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Papers on Hydraulic Engineering. By SAMUEL MCELROY, C. E.

(Continued from vol. xlvi, page 369.)

No. 4.—CITY SEWERAGE. (Continued.)

THE general characteristics of sewage disposal, and of ancient and modern practice, having been considered, it remains to deduce from this subject prominent principles of arrangement and construction in reference to general and specific plans, for the main trunk or *arterial* system, and the lateral or *venous* system, and their appurtenances, which will be noticed in this order.

Topography.—In any general plan of city sewerage, which properly includes the disposal of rainfall and the minor supplies, a careful study of the entire local topography is requisite, not only as to the area of the city proper, but as to all the lines and slopes of natural drainage which connect with it.

This forms the proper basis of the plans of main trunks or arteries, as to their location along the flow lines of the ravines, and prominently as to their sizes and forms, since it is shown that any adequate provision for storm flow, must be largely in excess of the house sewage discharge.

It also follows that a study of the primary, secondary, and tertiary ravines and their water slopes, controls the subdivision of these arteries in length and size, with reference to the special areas drained.

In this sense, the arterial system of any correct plan of sewerage, is independent of populated area, or population, and if properly arranged at the outset will never give occasion for re-arrangement; and the propriety of careful and substantial construction, so far as the system may be carried out at any intervals of time towards its final completion, is clear.

The importance of this principle might be strongly urged; it is a safeguard against all future trouble; the accidents of populative increase, or change of water supply, or improvements in pavement, always find whatever is completed adequate to all demands; and the long schedules of public and private damages, which are thus avoided, are negative witnesses of its superior economy, as a question of cost.

Outlets.—The places and method of discharge for these arteries, vary in convenience and propriety in different localities, and demand careful scrutiny. The question of atmospheric and hydraulic contamination, has justly received in cities like Amsterdam, Hamburgh, Paris, London, Boston, and many others, exposed to tidal re-actions or sluggish receptacles, the most earnest attention, and in some cases induced very costly constructions of artificial intercepting outlets.

In the case, however, of tidal streams of considerable size, or any body of water in constant motion, there is room for question, in more than one instance, whether the cost of interception would be justified, with a system of sewage disposal properly charged with water supply, since contact with large bodies of cool water and aeration, have a powerful protective influence over the objectionable qualities of sewage. There may be an extreme in apprehension as in neglect of proper care, and popular prejudices are often permitted to overrule intelligent and safe counsels, as we have had several occasions to notice, where valuable and economical water supplies were rejected from erroneous doubts of their quality, on assumed impregnation. Both at London and Paris, it is possible that a slight contraction of the Thames and Seine, so as to ensure a positive current, would be safer in a sanitary view, than the extended intercepting areas of sewage flow, which, in the former case particularly, is almost certain to be returned to the city with each flood tide, and deposited at slack water.

Sewer discharge into sluggish basins or receptacles of any kind, which accumulate deposits, is highly objectionable.

The use of pumping power to obtain an artificial outlet, where natural fall is denied, is a very simple, effectual, and often economical process. There is no mechanical difficulty in pumping sewage, and with the high standard of duty in engines of correct design, the annual cost is not formidable, and may be largely overbalanced by resort to other expedients for drainage, under an erroneous impression of cost. If, at Chicago, no advantages in a mercantile way, and in other respects, were realized by the gradual elevation of the streets and buildings, the use of pumps to obtain outfall would have been clearly justified, as a matter not only of economy but of superior efficiency. At New Orleans, unquestionably, a system of sewers with

artificial outfall, would redeem the sanitary reputation of that important city.

Advantage is sometimes taken, with success, of intermittent water supply, as at Hamburgh, Jersey City, Savannah, and other places, to flush the main sewers, where natural inclination cannot be had, and in the case of Savannah particularly, the results, with a very slight inclination, prove satisfactory. In the case of arterial systems exposed to tidal re-actions, the use of simple outfall gates may operate as flushes, with certainty. But it is evident, that intermittent or automatic arrangements of this kind are not comparable with constant, self-acting grades, and should be restricted to cases of special necessity.

Location and Form.—The proper location of the sewage arteries is along the drainage ravines or flow lines of the principal water shed slopes of the general area to be provided for; and they should be adapted in form, size, and grade, the three elements of discharge, to the ultimate requirements of their special supply areas.

The form of trunk mains, is somewhat controlled by the materials used in their construction, circles and ovals being most convenient for brick-work, where a different section is required for stone-work of moderate cost.

For sewers which exceed five feet in diameter, stone-work lined with brickwork, with a compound section, nearly vertical at the sides, combines strength, durability, and facility of flow. For those between five feet and forty-two inches, (which is the proper limit to arterial size,) brick-work is the most convenient, and the oval form with the minor curve at the base, the best; but the selection of sewer and aqueduct bricks should be made with great care, to secure thorough burning, since when exposed to dampness they need very compact section, nearly impervious and indestructible.

For the more common size of trunk sewers, the oval form has the advantage of a constant and concentrated current during the ordinary periods of house discharge, in which the city water supply is carried off; and of an increasing discharge section for storm flow, as the water area is increased; it also admits examination and repair more fully than a circle of the same area.

By reference to the Table given under the head of *Rainfall*, p. 454, vol. lxxvi, the relations between section, inclination, and discharging capacity, will be found as guides for the arrangement of the primary, secondary, and tertiary mains in subjection to their drainage areas; and the gradual concentration of drainage, towards the principal artery, from its branches, will control its conditions of arrangement.

Tubular System.—The arterial system which has been presented, belongs to the more general and rude division of the work, while the precepts of theory and practice point out the venous or tubular system, as the most delicate in its order, and the most vital in its effects.

For all cities of any important size, the use of trunk mains is desirable and proper, in their legitimate places, and should not be neglected; but the laws of sewage flow, also demand, in all the subordinate branches of discharge, the use of laterals, which will properly

solve the problem of "adequate disposal in the shortest time," and these should be pipes.

The same principle of arrangement which establishes the conditions of a trunk main by its drainage area, should also control the several groups of pipe feeders, which convey to it their several district accumulations, by their own laterals and mains, and which vary from 6 to 24 inches in diameter, and range from 1 to 115 acres in drainage capacity, on inclinations of 1 in 60.

This network of veins, not only admits the most careful adjustment, and secures the greatest economy in first cost, but also illustrates the principle of concentration of flow, by which the ordinary water supply is enabled to act with full power on all the substances which disposal of sewage includes.

In the arterial system, moderate inclinations are, as a general rule, controlled by natural formation along their lines, and involve a condition of safety, on this account, under the discharge of large bodies of water; but in the venous system, greater inclinations are natural and advantageous to the reduction of calibre.

But since it has happened in some cases, where trunk mains have occupied the place of pipes, that their outlets have been surcharged under storm flow, it is erroneously concluded that their size was inadequate, whereas the fault lay in their great rapidity of lateral supply under objectionable grades, which accumulated on their outlets, suddenly and uselessly, masses of water, that might have been properly disposed of by a more correct system. Pipes, therefore, are useful to their trunk mains, during storm flow, in preventing effects which have been used as arguments against their adoption; and they do this, without risk of being themselves surcharged.

In every arrangement of city distributing water pipes, the lengths of large mains form a limited proportion of the aggregate length of pipes laid. Of 120 miles of pipes specified in the Brooklyn Water Works contract, 64 miles were 6 inches in diameter. In Boston and many other cities, an important proportion of the water pipes is less than 6 inches in calibre; and the ordinary size of house service tap is one-half or five-eighths of an inch.

If then water supply, as is shown under the head of *House Sewage*, is a correct measure of the ordinary sewage flow, with what propriety can any engineer construct sewers 48 inches in the clear, in the same streets and for the drainage of the same blocks of buildings supplied with 6-inch water pipes? It is true that the supply is delivered under pressure, while the discharge must be by much less head, and that storm flow must be accommodated; but with liberal allowances for these conditions, any study of water supply in most of our cities, emphatically condemns the proportions of their sewers.

In the *Analysis of Sewage* it is shown that the proportion of solid matter is rarely as high as 1 in 142, is generally assumed at 1 in 600, and is sometimes less than 1 in 1000; we see then, the abundant natural provision which exists for the prompt and complete re-

moval of all the noxious constituents of sewage, before they can become injurious.

To accomplish this, however, it is necessary to secure a concentration of flow, in the channels of discharge, so that the scouring action of the water may be fully realized, by its force and direction, and this end can only be accomplished by a system of pipes, in its greatest perfection.

This point is very clearly illustrated, by the experiments of Mr. Blackwell, mentioned under the same head, which show the remarkable power of water currents in moving insoluble materials of great specific gravity.

For the discharge of a given body of water, a reduction of section, involves an inverse increase of velocity; and while this applies directly to the comparative efficiency of large and small branch sewers, it must also be remembered that a direct impinging current has a power greatly superior to the same current striking at an angle, or finding free vent above or on either side of any obstructing deposit. The impact of a thread of water is measured by its angle of incidence and its departing velocity, and maximum effect is obtained when these are a minimum.

The whole theory, then, of the venous or tubular system of sewerage, as subordinate to the arterial system, is based upon its complete concentration of flow, for ordinary discharge, at the time and in the places where perfect action is most desirable; and upon its more perfect adaptation to the contingencies of storm flow.

In this case, as in every other case, principle vindicates itself in the field of practice, by a mass of corroborative testimony which abounds, in a negative or affirmative form, in every system of sewers, from the remote Past to the speeding Present.

In those instances where the venous system has been ignored, and disproportionate sewers constructed, the results have amply condemned the practice, as to cost, sanitary evils, damages from floods, and annual expense of administration; built for convenience of entrance and cleaning, they have needed constant visitation and most costly excavations; of 69½ miles of sewers examined in the Surrey and Kent districts of London, the deposit was usually about 2 feet in depth, and in some cases 5 feet, reeking with foul gases, subject to explosion and choke-damp, and in an advanced state of decomposition; in New York the expense for repair and cleaning on 107 miles, was $45,921 in 1860, a sum which nearly doubles the entire annual sewerage administration of Brooklyn, on about the same length; as spacious reservoirs of deposit and offensive gases, they furnish food and harbor for vermin, while surcharging the atmosphere with hurtful exhalations; as peculiarly subject to overcharge in storm flow, they have been fruitful sources of public and private danger, while in strength and durability they do not compare with their more compact rivals; in point of cost, the balance against them is excessive; and from necessary roughness of line and surface, their excess in friction is not less than twenty-five per cent. on the same wet perimeter.

Pipes are therefore to be preferred as impermeable; capable of close and firm joints; smooth in surface and regular in form; of great strength; of maximum capacity for discharge; as self-cleansing; easily transported, handled, and laid; moderate in cost; and highly efficient.

Section.—In some cases of tubular systems, the oval section has been carried through all the ranges of calibre in the several groups; but, from 18 inches diameter, down to house connexions, it is doubtful whether there is any benefit realized, to balance disadvantages, in manufacture and laying. In Brooklyn the pipes of 24 inches calibre are made with an oval section of about 29 by 19 inches, which is the form lately introduced in New York, Albany, and some other places, but smaller sizes are circular, and can be more carefully made and jointed. Since, with half their section as water area, a 6 inch pipe, on a grade of 1 in 65, has a velocity of 4 feet per second, and an 18 inch pipe on a grade of 1 in 294, 3 feet per second, there can be no special advantage in improving the scouring power of the current by a reduction of the lower part of the section.

The effect of comparative perfection in surface and form for water conduits, is much more important than usually supposed. Between brick-work and earthenware unglazed pipes, a difference of 25 per cent. has been experimentally shown in favor of the latter, and between the *red pipe* and the *stoneware* pipe, experiments given in Appendix 2, page 179, London Report of 1850, show 15 to 31 per cent. difference in favor of the latter.

Perfection of form and surface is thus important, and also perfection in joints. In some of the cases of stoppages found in London and other pipes, defective joints were shown to be the arresting cause, and the difficulty which attends the perfect manufacture of earthenware pipes, has had a great deal to do with their slow adoption in some localities.

Inlets.—Pipe discharge is also seriously increased or modified, and efficiency of action promoted or hindered by the form and action of the lateral inlets. These should invariably be curved or inclined towards the line of discharge. The doctrine of "resolution of forces" is illustrated by some remarkable experiments on inlets, all of which go to show an important increase of flow in the receiving conduit, with proper inlets. In one case given Appendix 2, page 192, Report of 1850, ten inlets increase the main current 50 per cent. in velocity; in other cases the gain is stated at 300 per cent.

Materials.—The extensive use by the ancients, of earthenware pipes, many of which are still in operation, and, as we have seen at Zurich and other localities under excessive pressure, settles the question of their strength and durability. Experiments made in London, Brooklyn, and other modern cities, fully confirm this point.

But a careful discrimination must be made, between stoneware pipes, as of European manufacture, from fire-clay, and the best specimens of American manufacture, and clay pipes of coarser materials, imperfectly burned, and of irregular form and section.

On the materials of the Brooklyn pipes, Mr. Adams, in his Report of March 19, 1859, remarks:—

"The pipe imported during the past season for use in this city, from Glasgow, Scotland, and the north of England, are entirely different from the above, being manufactured, to appearance, of a strong fire-clay, resisting a high heat, and admitting of any required thickness and consequent strength. This description of pipe is believed to be less *brittle* and less *liable to fracture* in the handling, and better suited to the purposes of a sewer than pottery-ware. It is required to be of greater thickness and to be well burnt throughout, and rendered impermeable by the glaze, which *should have become incorporated* with the material of the pipe, and not liable to separation from it. The clay for this description of pipe is found in this country, but there has been too little demand for it hitherto to encourage its manufacture. The Chelsea Pottery Works, New York, have made some trial pipes of this description which show great strength, and suitable for sewer pipes, but have not yet been brought to the requisite degree of *finish in form*,—this accuracy of form, being regarded of even more importance than a smooth interior."

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"In packing the pipe in the press for the purpose of experimenting, many pipes were broken by the unequal bearing and cross strain induced by the effort to effect a tight joint at the ends, which in burning necessarily had become *more or less warped*, hence the pipe was badly strained before applying the hydraulic pressure. We have proved them with a head of 150 feet."

The italics in these quotations, present some of the defects to which burned pipes are liable, viz: brittleness, defective glazing, and irregular forms. The losses by breakage in handling and transportation are sometimes quite large; in those cases where the burning and glazing are imperfect, the effect of moisture gradually destroys the pipe; while an irregular or excessive heat warps the lines and joints. Earthenware pipes therefore require great care in manufacture and selection, and in this country they still fall short of the European standard of stoneware.

For reasons of this kind, and the objections to importation, preference has been given in Brooklyn and some other cities, to pipes manufactured of concrete, made from hydraulic cement mortar and beach gravel, very carefully mixed, and moulded under pressure. These pipes have great perfection in form, since the process fully admits perfect moulding, and, in common with other preparations of cement mortar, which has been thoroughly mixed, so as to avoid "drowning" on one hand, and to secure crystallization on the other, their strength is increased by age and insured by moisture. They "set" rapidly, so as to become abundantly hard in six weeks or two months: are easily fitted with branches and nipples, by any mason, in the trench; are easily transported; and are cheaper for sewerage than stoneware or brick-work. A number of miles of this kind have been laid in Brooklyn, and the entire theory of hydraulic construction, confirms the principle of their manufacture. Built on polished cast iron cores, their internal curves are exact duplicates of each other, so that perfect lines of discharge may be laid, with close socket joints, and with great smoothness of surface. In friction, durability, readiness of manufacture and cost, they may be considered the best pipe sewers in use.

Exhalations.—The use of comparatively small pipes which maintain a continuous flow, not only ensures the sanitary benefit of prompt

removal for sewage matter, but also controls the air currents of these laterals, so as to carry them in the line of flow. This effect of a running stream in contracted channels, reverses the action of the system superseded, as to exhalations of noxious gases, with benefits of no ordinary value to populated districts.

Appurtenances.—These, in modern practice, consist of man-holes, lamp-holes, and street basins.

In European cities, where the street pavement is much used, access is had to the sewer by entrances from the side-walk, or some point in its vicinity, so that the work of cleaning and examination does not interfere with carriage travel; these entrances are large inclined culverts. In our cities, vertical shafts are built, from the sewer centre, generally at street intersections, or at convenient distances for cleaning.

In Brooklyn the man-holes are built of brick with an elongated working section of 4 by 3 feet at the sewer, and reduced to 2 feet diameter in the shaft, which is capped with a cast iron cover on a granite frame, or by a better pattern, on a cast iron frame at the pavement grade. At summits and other points intermediate between the man-holes, shafts of brick-work or pipes, (the latter 9 inches in diameter being the most simple,) are built to pavement grade, to be used as lamp-holes, when examinations are desired from the man-holes.

For the flow of street water into the sewers, street-basins or gullies of various forms and devices have been used in different localities. These properly belong at depressed points in gutter grades, and more particularly at street corners. They are of great use in preventing long currents of storm water from interrupting pedestrians, and damaging pavements and property, and facilitate the construction of street railways and other public improvements; they are also of great sanitary value, in preventing the common evils of gutter decomposition where gutter flow would not otherwise be properly provided for.

These basins have various forms; their office is to collect the dirt washed from the streets, while passing the storm flow into the sewers, with which they are connected by culverts or pipes; in Brooklyn pipes are used 9 inches in diameter; they are also, in modern practice, built with a trap-wall, to prevent exhalations into the streets; for the wash of cobble stone or Macadamized pavements, the use of a chamber which will contain 4 or more yards of *detritus*, and prevent its passage into the sewer, has some advantages, and is a necessity in all those cases where the sewers they connect with are not self-cleansing, but they must be cleaned at intervals, involving a costly and disagreeable operation; for this reason, where the double advantage of cleanable street pavement and self-acting sewers can be had, the basins should be built with a low discharge pipe, so as not to act as retaining wells.

An occasional want of care in the foundations of street basins and man-holes is shown by settling, which breaks joints and tubes; here the use of concrete may be strongly urged, as furnishing the most perfect base at the least cost.

Of the various details of construction for pipe sewers, as to careful lining and grading; careful bedding and tamping; the use or disuse of cradles, or grillage in soft beds; the advantages of socket joints; the position and form of inlets; the regulations proper to administration; the relative cost of various parts and kinds of work; the use and objections of tunnels in difficult cutting, and the like, much might be said of a practical nature, which we pass over, as questions rather of special application, in a discussion of general principles.

Back Drainage.—The usual system of house drainage, is by separate drains leading from the back of the lot or house through the cellar or foundation, to the street sewer. This is known as the system of *front drainage*, in distinction from a system introduced in London, to a considerable extent, by which advantage is taken of the usual arrangement of city blocks, to make the drainage entirely through the rear lots, with outlets in the side street sewers. On this point the Report of 1850, Appendix 2, page 116, thus remarks:—

"The bulk of the drainage and the most deleterious portion is generated chiefly at the backs of the houses, and would, under the old system, be sent from thence through the house to the sewer in front, having to travel through the greatest possible space, with the least possible velocity and with the widest diffusion of the flow. In the formation of the system the disturbance of the flooring, joists, and walls of the houses, of the roadways and public streets, peculiar to this system, or of far greater amount than in the back system, to the annoyance of the inhabitants and interruption of public transit, is certainly a consideration of much weight."

On page 140 this theory is illustrated by reference to examples in practice, from which it appears, among others, that in one block of 23 houses, the lengths of front and back drains were as 1437 to 783, and the cost £131 13s. 6d. to £45 12s. 6d.; in another case of 46 houses, the lengths were as 1892 to 1143 feet, and the cost as £178 19s. 8d. to £66 5s. 2d.

Evidently, many cases occur in the arrangement of city sewerage, where this theory may be applied with great success, both as to economy in cost and as to improved action.

Conclusion.—We have attempted to group here the leading principles of correct sewerage, as illustrated by past and present experience, and put on record for the benefit of constructors. It is a subject, as will readily be observed, of too wide a range and too important a character, to be comprised in sketches of this kind, made with the outlining *porte crayon* and *currente calamo;* but if they serve to direct more careful study to their theories and to promote the advancement of educated practice, or to correct any existing evils, their purpose will have been accomplished. It may be said additionally, that it is scarcely necessary for the collaborateur to disclaim originality.

On the Construction of Wrought Iron Lattice Girders.

By Thomas Cargill, C. E.

(Continued from vol. xlvi., page 383.)

From the Lond. Civ. Eng. and Arch. Journal, Nov., 1863.

In all joints to which the definition given in our last is applicable, the actual sectional area of the plates at the line of the joint was stated

to be equal to zero. Theoretically this statement is equally true for joints which are under either a tensile or compressive strain, but, practically, far more so for those under the former than under the latter condition. It is therefore apparent that the same joint, by which is meant exactly the same number and disposition of rivets and length of covering plates, is not so well adapted for one portion of a girder as for another. The joints, then, in the top and bottom members of the girder should not be identical. This also follows from the fact of the rivet holes unequally affecting the strength of the plates composing the upper and lower booms. In all girders, however, where the span is of such limited dimensions that the sectional area of the upper and lower flanches is the same, it would be unnecessary to make any difference in the jointing of the plates or angle-irons, more especially as the difference would lie on the safe side.

It would be impossible to construct a joint in a manner so that theoretically the value of the plates at the joint should equal that of any other portion of them, which would be equivalent to making $b\,t=(b-n\,d)\,t$, in which the minimum value of n must be equal to 1, and consequently $b=(b-d)$. If we take into consideration the additional strength and assistance afforded by the covering plates, the effect of friction, small though it may be, and look at the whole joint in the light of a firm and secure combination of parts, in many instances, practically speaking, the joint no doubt is as strong, and in some particular situations, stronger than the original plates.

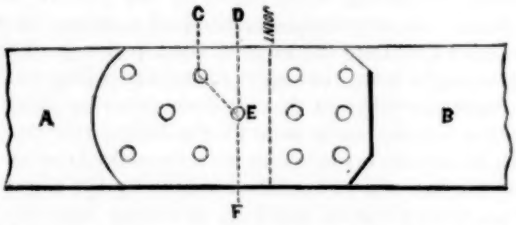
To return to the subject of the disposition of the rivets and form of joints. Let us take the case of the two plates A and B in Fig. 1, which are of breadth sufficient to take three rivets across the plates. Make s and s_1 equal the net sections of the plates. s from the figure will equal $b\times t$. s_1 will equal $(b-n\,d)\,t$. If n be the number of rivet holes in the plates at the joint, and n_1 the number elsewhere where no joints occur, $\frac{s}{s_1}=\frac{n_1}{n}$. In any joint the very least value of n must $=1$, and consequently the maximum value of s_1 is $s_1=s-d$. The difference between the actual section s_1 and its maximum section, will altogether depend upon the manner in which the rivets are disposed in the joint. It is evident that the joint, so far as the plates were concerned, would be strongest if the section taken through the rivets in any direction across the plates were equal to $s-d$. Let $s-d=$ section taken along line DEF (see Fig. 1), if the section be taken along any other line, such as GEF, we obtain an increase of section, and also a loss. Let $s=$ the increase, then in order that the plate might be equally strong in any other direction as GEF, we have the following equation, putting n_1 for the number of rivet holes along the line of section:

$$(s+s-n_1d)=(s-d),\text{ and }s=d\,(n_1-1).$$

It is not often that n can be taken $=1$, so that a more general value for the above equation will be $s=d\,(n_1-n)$. Let $x=$ the distance of the centre of the first rivet from the edge of the plates,

and put b as before for the breadth of the plates, and d for the diameter of the rivets: then $b = 2x + 2\frac{(2x+d)}{2} = 4x + d$. The minimum value of $x = 2$ inches, and therefore, for a plate to take three rivets across its breadth, b should not $< (8 + d)$. In order to determine the breadth of any plate to allow of the insertion of a certain num-

Fig. 1.



ber of rivets across it, put n, x, b, and d as before, and for a general formula $b = 2x + (n-1)\frac{(2x+d)}{2}$, from which we obtain $b = 2x - d + n\frac{(2x+d)}{2}$. The exact pitch of the rivets will depend upon the description of strain which the joint to which they belong undergoes. Let p = the minimum pitch which the rivets should have in a joint exposed either to a tensile or compressive strain; and employing the same notation as above, $p^2 = \left(\frac{2x+d}{2}\right)^2 + \left(\frac{2x+d}{4}\right)^2$; and, reducing and equating, $p = \sqrt{\frac{5x(x+d)}{4} + \frac{5d^2}{16}}$. In a joint exposed solely to a tensile strain the pitch, if alternate, should be at least $= \frac{3p}{2}$, or even more, if the covers are to be well stretched and the strain properly distributed over the whole joint.

But although joints are supposed to be acted upon by either compressive or tensile strains, according to the position they occupy in the girder, and may be designed for each particular description of strain, yet it would be going too far to state positively that any portion of a girder is always subject to one kind of strain, and that it never undergoes any other. However complete our knowledge may be of the nature and effect of the different strains produced on a girder, by such loads as a weight at the centre or a uniformly distributed dead weight, it is far from perfect respecting the strains resulting from the varying action of a movable load, such as a railway train for instance. Strains of a totally different character from the normal ones are undoubtedly produced by a live load moving with

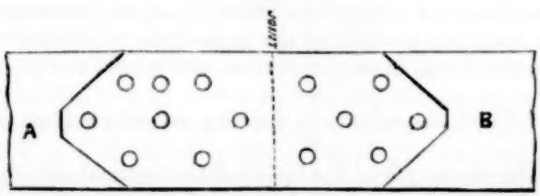
even moderate velocity. As an ordinary example, take the case of a bridge consisting of two wrought iron girders, designed to carry a double line of rails on cross girders which are placed close to the bottom flanges. When a train is passing over the bridge, let the top flange of the main girder furthest from the moving load, or what might be called the girder carrying the opposite line of rails to which the train is on, be attentively observed, and it will be found to deviate in a zigzag manner from its former position, thus showing that a considerable amount of torsion is produced by the partial distribution of the moving load. A very simple method of making the above observation is as follows. Along the edge of the top flange of the girder fix three or four upright laths, or insert more, according to the length of the girder. Place the laths so that all their inner or outer edges (that is, all the edges on the same side of the laths) are out of winding. The observation may be made either with the naked eye or a telescope. The effects of torsion will be rendered visible by the edges of the laths which were previously out of winding, deviating laterally as the load advances over the bridge. A more accurate observation could be effected by having all the laths of the same size and placing them out of winding, but as the edge of the flange of a girder is never itself strictly out of winding throughout its whole length, it would not be easy to make both edges of all the laths to coincide. There would also be a vertical deviation of the tops of the laths supposing them to be all of the same height, but this would be simply the result of deflection, the effects of which can be calculated with sufficient practical accuracy.

With respect to the effects of torsion, which may be observed in the manner indicated above, three cases present themselves. The first and simplest instance is when the bridge consists of two main girders, carrying only a single line of rails. The lateral leverage of the moving load, supposing it to be placed as we have mentioned, is equally distributed upon the two main girders, and although some torsion will be produced, the principal effect is to draw the tops of the girders together. Another instance occurs when there are three main girders, the centre girder being made twice as strong as the side ones. This case is precisely similar to the former, provided that the cross-girders are not continuous. The side girder will however exhibit a greater deflection and a larger amount of torsion than the central one. If the cross-girders are continuous, the moving load takes effect upon the side girder belonging to the other line of rails. Let s equal strain on central girder produced by a moving load, and s_1 that produced by the same load on the side girder furthest from the load, let e equal gauge of railway, then $\frac{s}{s_1} = \frac{3 \times e}{2} \times \frac{2}{e} = 3$. The third case is the one described before, in which the double line is carried by two main girders. The resistance of the side girder furthest from the moving load will in this instance be greater than when there are three main girders, although the leverage remains the same.

In Fig. 1, the joint as shown belonging to the plate B is evidently

a more economical one, so far as the wrappers are regarded, than that of the plate A. Let l, l_1 = the half lengths of the wrappers for the plates A, B, respectively, $l = x + np$, $l_1 = 2x + (n-1)\,p$, and $l - l_1 = p - x$. The difference however would be much greater than that given in the equation, for the value of p would not be the same for both tensile and compressive joints; for the latter of which the joint at plate B is best suited. There is also a great dffference in the value of the net sections, which are in the proportion of $\frac{n}{n_1}$, or as 3 : 1. In the case of B, the net section would be considered nearly equal to that of the plate, especially if the riveting were performed by machinery. The same description of joint is represented in Fig. 2, with a slight modification in the shape and length of the wrappers. A difference may be also here observed in the disposition of the rivets next the joint; in the plate B there are two rivets equally distant from the joint, while there is only one in the plate A. If a strain sufficient to cause fracture were applied, the ultimate net sections, or the line of fracture, across the plates would be the same, the pitch of the rivets being similar. In a joint exposed solely to a compressive force the rivets might be arranged in either manner, although the arrangement in plate B would be the preferable one. The contrary will be the case where the strain is of a tensile nature, in consequence of the shearing force induced in a longitudinal direction upon the plates. Let H = the tendency to draw the rivets nearest the joint, through the plates in the above direction, n the number of rivets equally distant from the joint, c the distance; then, the diameter and number of the rivets being the same $H :: \frac{1}{c}$. It will be seen that, in the plates A and B in Fig. 2 since the value of n and n_1 are different, the shearing forces are as 1 : 2, or more correctly speaking, the tendency to bring the shearing force into action is as above.

Fig. 2.



It would be needless repetition to give any more examples of joints of simple plates, in which the difference would consist merely in the dimensions of the plates. Whatever the breadth may be, the formula $b = \frac{(2x-d)+n(2x+d)}{2}$ will always hold, and the number of rivets to be inserted in the breadth of the plate will equal n, and $n = \frac{2(b-x)+d.}{(2x+d)}$ The same principles will equally apply respecting the disposition of the

rivets so as to distribute the strain uniformly over the wrappers and plates, and the judgment and experience of the designer must supply those trifling variations and modifications which inseparably accompany the application of general rules to particular examples.

We now will proceed to the consideration of a joint which is of constant occurrence in practice—viz: the jointing together of two plates forming the portion of a boom of a double-lattice girder. In order however to distinctly point out the effect which the riveting of the longitudinal angle-irons to the plates has upon the disposition of the rivets at the joint, a plan of one of the plates is shown in Fig. 3, where no joint occurs. The figure represents a portion of the inside of one of the plates, with four, or two pairs of angle-irons united to it by uniform longitudinal rows of rivets, equally pitched from centre to centre. Between each pair of angle-irons are riveted the bars composing the web of the girder. The sectional ends of the bars as well as the connecting rivets are not shown in the figure, to avoid confusion, besides they are not required for our present purpose. To obtain the advantage of the full breadth of the plates, and to keep the distance between each pair of angle-irons as great as possible, the first angle-iron of each pair is always placed flush with the edge of the plate. It is obvious from this arrangement, that the four longitudinal rows of rivets shown in the

Fig. 3.

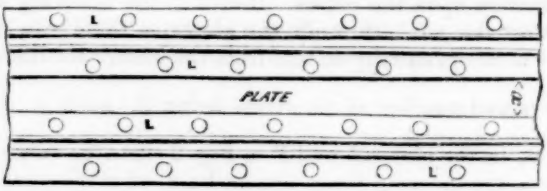


figure are at once determined, or what amounts to the same, the position of four rivets in the breadth of the plates is fixed independently of any other joints or connexions which it may be necessary to make. Let l = the length of the side of the angle-irons which is riveted to the plates, then the distance of the centres of the first row of rivets from the edges of the plates will $= \frac{l}{2}$, l being measured from out to out; that is, if l_1 be the length of the inside of the vertical side of the angle-irons, and t the thickness of the horizontal sides, $l = l_1 + t$. Similarly, putting m for the maximum thickness of the web, which will correspond to the space between each pair of angle irons, we shall have the distance between the centres of the first and second rows of rivets equal to $l+m$, or the distance of the centres of the second rows from the edges of the plates equal to $(2l+m) - \frac{l}{2} = \frac{3l}{2} + m$. The value of m will in general be the sum of the thicknesses of the two thickest ties and struts in the web. Its exact value will depend upon the manner in which the

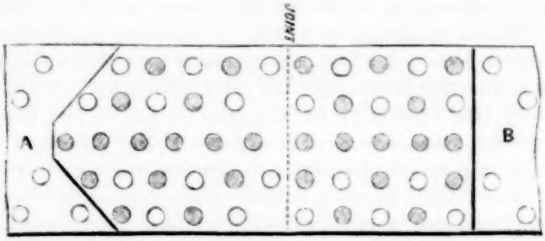
struts are riveted in between the angle-irons. The thickness of any strut or tie is a maximum at the abutment, and a minimum at the centre of the girder; it therefore becomes necessary, in order to preserve the distance between each pair of angle-irons constant, to insert filling or packing pieces between the ends of the bars and the angle-irons. If t be the thickness of the web at any point, p the thickness of the corresponding filling piece or washer, $p \propto \frac{1}{t}$. The limits of p will range between $p = 0$ and $p = m$. A very large proportion of the packing pieces might be got rid of if the second angle-irons of each pair, instead of being maintained at a constant distance from the first, were riveted to the plates in a line gradually converging towards the centre of the girder so as to regularly diminish the space between them. The practical inconveniences and chances of error attending the punching of the holes in the plates in the above manner would not justify its adoption of girders in ordinary spans, where the saving of material would be inconsiderable.

As the longitudinal angle-irons connecting the booms and webs must be attached to the plates by regular rows of rivets in a manner similar to that shown in Fig. 3, either with an alternate pitch or otherwise, it is practically impossible to design the joints for the plates in the best and most efficient manner, as would be the case were there no angle-irons riveted to them. In fact, the rivets required for this purpose virtually determine the description of joint which we are able to employ. The result of this limitation is, that the joints in the flange plates of ordinary girder work are nearly always better adapted to resist the strain on the top boom than on the bottom, for which they are most required. Very little room is left for the exercise of the judgment of the designer, and not much more can be done than to take care to insert a sufficient number of rivets to hold the plates and make as good a joint as possible under the circumstances. The truth of this will be perceived on examining Fig. 4, which represents the reverse sides of the plan in Fig. 3, with the addition of a joint and wrapper, and in which the plain circles are the rivets inserted through the plates and angle-irons, and the shaded ones those necessary to complete the joint. It will be found, on observing girder work, that if p = the pitch of the rivets such as shown in Fig. 3, as a general rule the pitch of the rivets in the joints will equal $\frac{p}{2}$. Two arrangements of the rivets for the joint are given in Fig. 4, the one on the right on plate B being very frequently employed, although it is not so well suited for the lower boom of a girder as the other on the left on plate A. Let s = section of plates in a straight line across the plates, and c any increase of section arising from s not being in a straight line, then $(s - nd)$ will be the available amount of metal in the plates wherever s is taken in one continuous straight line. In plate B the minimum value of n is 5, in plate A with section s its minimum is 2 and maximum 4. It has, the same as in plate B, a maximum value of 5, but then the section is no longer s, but

(s+c). For the joints in the lower flange of a girder, where the tensile strain tends to separate the plates or pull the joint asunder, there is a slight advantage gained in disposing the nearest the joint, as shown on plate A. Let p = the alternate pitch of the rivets, and let n, n_1, n_2 = the number of rivets nearest the joint in plate A, which are respectively at equal distances from it, similarly put m for the number nearest the joint in plate B. The resistance of the former plate in comparison with the latter, against the calling into play of a longitudinal shearing force, will be as $\frac{p}{2}(n+n_1+3n_2) :: \frac{p}{2} \times m$;

substituting the values for n, n_1, n_2 and m we have the ratio as $\frac{9}{2} :: \frac{5}{2}$. Whenever the pitch of the rivets in the plates and angle-irons is not alternate, the simplest joint is made by inserting a rivet in each row halfway between the others, and adding as many additional rows as the breadth of the plate will allow, until the proper number is put in. The joint will then be precisely similar to the one in plate B, in Fig. 4. In large girders, and wherever the importance of the work demanded it, an interruption in the regular punching of a portion of the plates

Fig. 4.



near their ends, and of a corresponding length of some of the angle-irons, must take place, otherwise the joints cannot be designed and the rivets inserted in them to the best advantage, particularly in those joints which, from their position in the girder, would be exposed to a tensile strain. It is manifest, under the most favorable circumstances, that the jointing of a combination of plates and angle-irons cannot be considered in the light of a simple jointing of two plates, and that some modification and departure from the most efficient disposition of the joint must ensue, although in important examples the correct principles may be adhered to with sufficient practical fidelity.

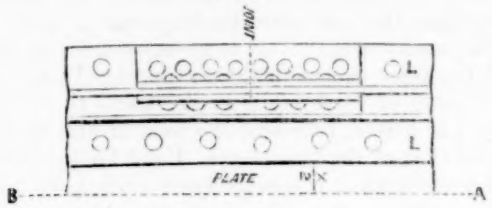
It should be borne in mind in designing joints, that the value of n being constant, the length of the covering plates varies directly as p, and therefore care should be taken not to spread the rivets too much. On the other hand, the rivets should not be huddled together, and a more than necessary amount of weakness produced in the plates, for the sake of effecting a small saving of material in the wrappers. It might be alleged that the thickness of each wrapper need not be greater than half that of the thinner plate to be jointed, or, what amounts to

the same, that the sum of the thicknesses of the wrappers should equal the thickness of the thinner plate. Theoretically this would give a sufficient amount of section at the line of the joint, provided the strains to which the joint was exposed affected it perfectly uniformly. But practically we know this not to be the case. The disposition of the rivets in the joints, the manner of loading, and a variety of other contingencies, frequently cause joints to be more strained in one part than another, and the same occurs in the wrappers. It will be far safer to make each wrapper at least equal in thickness to that of the thinner plate, or, what is better, to make the sum of the thicknesses of the wrappers equal that of the two plates. Put t for the thickness of each wrapper and t_1 t_2 for that respectively of each plate; then, for each wrapper to have the same thickness, $t = \frac{t_1+t_2}{2}$. On referring to Fig. 3, it will be seen that the wrapper of the inside of the plates will only occupy a breadth of the plates equal to x, and will not extend the whole breadth of the plates, like the outside wrapper in Fig. 4, but fit in between the angle-irons, which supply the remaining portion of the wrapper and act as such. In many instances, were it considered worth the omission, this small inside wrapper might be dispensed with. To obtain the maximum theoretical efficiency in a joint, the value of n should be infinitely great, and that of d infinitely small. In small girders, as before mentioned, in order to save trouble and inconvenience in punching the rivet-holes, the joints in the upper and lower flanges are generally made identical, but in girders of large span they should be differently proportioned. Let n and n_1 equal respectively the number of rivets required in the half joint of a plate subject to tensile and compressive strains. Employing our usual notation, and supposing the same constant employed for both, we have $\frac{n \times \pi d}{4} = n_1 \times t$, and $\frac{n}{n_1} :: \frac{4 \times t}{\pi \times d}$. As a higher constant might with perfect safety be used, we may take into our calculations the increase of strength afforded by the friction between the plates and wrappers, more especially if the latter be of considerable size, and also of the rivets themselves. We shall then find $\frac{n}{n_1} :: \frac{2t}{a}$, the value of n being increased in the proportion of $\frac{\pi}{2}$: 1, supposing the diameter of the rivets to be the same size.

Whatever may be the peculiar form or section of iron to be jointed, the same principles will apply, although a little artifice may be required to meet the exigencies of particular examples. In Fig. 5 a plan of the joint of one of the angle-irons in the flange of a girder is shown, AB being the centre line dividing the flange longitudinally. One of the wrappers consists of another piece of angle-iron, fitting into the main angle-iron, which answers the double purpose of one horizontal and one vertical wrapper. The other vertical wrapper is supplied by a piece

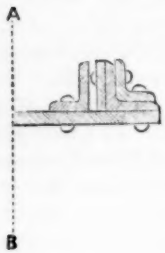
of flat iron placed as shown in the figure. The other horizontal side of the joint is covered by the main plate of the flange, and therefore no second wrapper is required in addition. This arrangement is better

Fig. 5.



represented in section, in Fig. 5*a*, the line AB dividing the flange vertically at right angles to the line AB in Fig. 5. The length of the horizontal and vertical sides of the angle-iron wrappers should be such that they should not project beyond those of the angle-irons to be jointed, but be flush with their edges, as in the section referred to. To give it the same sectional area, it must thus necessarily have a greater thickness than the main angle-irons. Let A = area of main angle-irons, and A_1 that of the wrapper, then, as the value of n will be the same in both instances, $A_1 = A$. Put l and l_1 for the length of the vertical and horizontal sides respectively of the main angle-irons measured from out to out, and t for the uniform thickness, also let t_1 be the required thickness of the wrapper. A will then $= (l + l - t)\,t$, and $A = [(l-t)+l_1-(t+t_1)]t_1$, and we shall have the equation $t^2 - t_1(l+l_1-2t) = -t(l+l_1-t)$,* from which, solving for t_1, we obtain

Fig. 5 *a*.



$$t_1 = \pm\sqrt{\frac{[(l+l_1)^2 - 8t(l+l_1-t)]}{2}} + \frac{(l+l_1-2t)}{2}$$

For example, let the dimensions of the main angle-irons be $4\frac{1}{2}'' \times 3'' \times \frac{1}{2}''$, then the value of t_1 which will give an equal sectional area to the wrapper will be $t_1 = .595$, or practically $\frac{9}{16}$. The sectional area of the flat vertical plate acting as a wrapper will equal $(l-n)t$.

In making the drawings for the girder, care should be taken to show all the joints in the positions they are intended to occupy. If a mere general design and description be given, they will frequently be found to be placed in too close proximity to one another. Unless where unavoidable no joint should be at a less distance from another than three feet. On referring to Fig. 5, it is manifest that the joints in the angle-irons must be so arranged that they should not occur at places where the flanges are intersected by the bars of the web, otherwise the second vertical wrapper would have to be omitted. Independently of this consideration, it would be bad construction to place a joint in the

* This equation resolves itself into one belonging to the general class $x^2 - ax + b = 0$, one root being rejected by the nature of the problem.

angle-irons to which the bars of the web are attached, at the point where that attachment is made, and consequently the greatest amount of local strain induced. The same reasoning applies to the joint of the main plates of the flanges, but with much less force, since the strains are not received directly by them, but are transmitted to them by the longitudinal angle-irons, which also serve to diffuse them more uniformly over their surface. It would be well to cause the rivets placed vertically in the angle-iron joints and wrappers to alternate with those in the horizontal position, but this is not of so much importance in sections of rolled iron similar in form to that of angle or tee iron, as in flat plates or in plain bar sections. The effect of a strain to cause fracture through a line of rivet-holes in a plate, the surface of which was all in the same plane, would be greater than if the same amount of metal in the plate were rolled into a form having equal sections distributed in two planes at right-angles to one another, with half the rivet-holes in each plane.

(To be Continued.)

Observations on Foundations of B idges, &c By Thomas Page, M. Inst. C.E.,F.G.S.,F.R.G.S.

[Paper read to the British Association, 1863.]

From the Lond. Civ. Eng. and Arch. Journal, Nov., 1863.

It is not proposed in the following observations to give a history of foundations, but only to refer to the system pursued by the author in the various works he has executed under the water level without the use of coffer-dams, which, whatever may be their advantage, are a most expensive means of construction. It may be quoting an extreme case to refer to the repairs of the Old Westminster Bridge in the year 1838, where, in a contract for the repairs of that structure amounting to £49,500, the permanent work amounted to £14,500 and the coffer-dams to execute that work to £35,000. But viewing the subject of coffer-dams as a whole it possesses but little engineering merit, compared with its expense, as a means of construction in foundations.

The author's experience on this subject embraces the Thames Tunnel, of which he was Acting Engineer under Sir Isambard Brunel, from 1836 to its completion, a period which embraced the most difficult part of the construction of that great work (being nearly half its entire length) and also the formation of the shaft on the Middlesex side; it also includes the works of the Victoria Bridge, and the Albert Bridge, over the Thames at Windsor; the Chelsea Suspension Bridge; the New Westminster Bridge; and his design for the foundation of the Albert Pier at Greenock, carried into execution by Messrs. Bell and Miller, Civil Engineers, of Glasgow.

Principles of a Foundation.—A foundation may be described as that part of a structure which resists the weight of the superstructure; and it is evident that the higher the horizontal plane of the resisting mass, the less is the weight of the superstructure upon it, and the bet-

ter adapted is the foundation to resist its pressure. For instance, if, to follow out the injunction, "go deep enough to obtain a good foundation for the piers of a bridge," the resisting surface is 30 *feet below* the low-water line, while in another case the resisting surface is *level* with the low-water line, it is evident there is a pressure due to 30 feet in height of the material of the piers greater upon one foundation than the other. If this principle were always acted on—viz: to so construct the foundations that the plane of resistance should be at a high level—the difficulty of founding in deep water would be considerably reduced.

System of the Author as practised at the New Westminster Bridge.—The system which the author has pursued in the construction of the four bridges over the Thames before referred to, may be thus described. The positions of the piers and abutments having been accurately defined, bearing piles are driven deep into the ground over the area of each pier and abutment, at a distance of 3 feet between each pile. All the piles are driven to the same test, so that every pile is capable of supporting the same amount of load.

This result is not dependent on the length of the piles, for some piles attain the resistance to the test sooner than others, depending on the state of the stratum through which they are driven. In many bridges the piles have been specified to be driven to a specified length, but this condition did not secure equal degrees of resistance, which can only be attained by driving the piles to the same test.

The piles being driven, their tops are cut off at the low-water line of spring tides; and on the line of the perimeter of the pier cast iron piles are driven at distances of 5 feet 2½ inches apart, centre to centre, in which are grooves for the cast iron plates or sheeting piles. In Westminster Bridge these sheeting piles or ribbed plates were 16 feet in length and 4½ feet in breadth, and were driven down until the top flanges were 6 *feet below the low-water line*; the 6 feet in height from those flanges up to the low water-line, was formed of granite panels 2 feet thick instead of the cast iron piles, so that no iron but the main piles appears in the face of the piers to a depth of 6 feet below the low water-line. The timber piles are then tied to each other and to the iron piles by wrought iron bars, and two tie-bolts were inserted at the head of every sheeting pile 7 feet below low-water, and a tie-bolt to every main pile at the *low-water level.*

The bed of the river was then cleared of all loose materials down to the hard gravel, and in many cases down to the clay, and the spaces between the piles were filled with concrete made with Portland cement and gravel, which concrete was deposited from boxes (opening with flaps) on the bed of the river, and which concrete soon became as hard as a rock. All the upper surface of the pier was then brought to a true level for the reception of the great base course of granite, and on this granite floor the pier was carried up with brick-work and granite.

To avoid the scour round the piers, which is felt at all the bridges of the metropolis in every case where any set of the current strikes the pier in an oblique direction, a base of Portland cement concrete was deposited round the piers of the New Westminster Bridge.

On the Foundations of the Chelsea Bridge.—In the Chelsea Bridge the casing of the piers was of cast iron, the main piles being 9 feet apart (central distance) and the sheeting piles and plates being 7 feet 2 inches in width. As these were carried to a level of 7 feet above Trinity high-water, and to a depth of 41 feet below, there was a surface of iron 48 feet in height.

The proceedings in arranging and driving the timber bearing piles, tying them across by wrought iron bars, dredging the bed of the river, and filling all the spaces round the piles with concrete, were similar to the proceedings at Westminster Bridge, which followed Chelsea Bridge in point of time.

Of the Greenock Pier.—The introduction of granite slabs or panels at Westminster Bridge led to their adoption at the new pier of Greenock, the drawings for which, prepared by Messrs. Bell & Miller of Glasgow, Civil Engineers, were referred to me, at their suggestion, by Mr. Jas. F. Grieve, the Provost of Greenock. The alteration I suggested in the face work of the pier, instead of building it in courses on a principle patented by Messrs. Bell and Miller, was to form it by large granite slabs or panels each 8 feet high by 7 feet wide and nearly 2 feet thick, between cast iron piles; the front and back flanges of the iron piles were arranged for the granite panels to slip down between them, and as these panels were each 8 feet in height, an enduring face 16 feet in height was obtained at a considerable saving of cost, in the most simple and comparatively inexpensive manner.

The granite used at Greenock Pier is of fine reddish granite from a spacious quarry in the Isle of Mull, on the Estates of his Grace the Duke of Argyle, worked by the Isle of Mull Granite Company. This granite was also partly used at Westminster Bridge, with the Cheesewring, Haytor, and Par granites, and is admirably adapted for hydraulic works on a great scale.

Of the Piling of Old London Bridge.—It is worthy of remark that the bearing piles of Old London Bridge were cut off on the level of the low-water line, but it was without reference to this circumstance that the bearing piles of the Chelsea Bridge and those of the New Westminster Bridge were arranged to be cut at the level of the low-water line.

General Observations.—It is due to the British Association to state the reasons why the author prefers the system he has brought under the notice of the Section to the systems of foundations by cylinders of iron, filled with brick-work or concrete, which has been so generally acted upon during the last fifteen years. He considers it important that the foundation of each pier should be one undivided structure; that it should not be broken into separate parts, as it is in cases where cylinders are used, and that, besides the resistance due to the horizontal area of the foundation, it should embrace the additional resistance afforded by the friction due to the vertical surfaces of the piles; and thus, short of founding on rock itself, it would present the most solid resisting mass that could be formed.

The facility and rapidity with which such foundation can be formed

with a surface of granite or other durable stone, recommends itself for breakwaters in deep water in preference to the system of forming a slope with a large expenditure of material and labor, and it is to be considered that a vertical face is less dangerous to vessels approaching a breakwater in rough weather, as against it the sea would only dash without breaking, while on the slope the waves become *breakers;* and many instances have been known of ships being lost upon the slopes. For such a Harbor as Dover, which is built of concrete blocks faced with granite, all being set by divers, the formation of a granite face in panels, and the core filled in with concrete *en masse*, deposited in the same manner continuously as at Westminster Bridge, would secure a rapid and economical construction.

The application of this system of construction to harbors is a subject of great interest and importance at the present time, both for expedition in completing the works, and for economy, but as this paper is especially devoted to *foundations*, any further observations must be reserved for another opportunity.

MECHANICS, PHYSICS, AND CHEMISTRY.

An Investigation of Plane Water-Lines for Ships.

By Prof. RANKINE.

From the London Athenæum, Sept., 1863.

This paper contains an abstract of a mathematical investigation which has been communicated in detail to the Royal Society. By the term "Plane Water-Line" is meant one of those curves which a particle of liquid describes in flowing past a solid body, when such a flow takes place in plane layers. Such curves are suitable for the water-lines of a ship; for, during the motion of a well-formed ship, the vertical displacements of the particles of water are small, compared with the dimensions of the ship; so that the assumption that the flow takes place in plane layers, though not absolutely true, is sufficiently near the truth for practical purposes. The author refers to the researches of Prof. Stokes (*Cambr. Trans.* 1842) "On the Steady Motion of an Incompressible Fluid," and of Prof. William Thomson (made in 1858, but not yet published), as containing the demonstration of the general principles of the flow of a liquid past a solid body. Every figure of a solid past which a liquid is capable of flowing smoothly, generates an endless series of water-lines which become sharper in their forms as they are more distant from the primitive water-line of the solid. The only exact water-lines whose forms have hitherto been completely investigated, are those generated by the cylinder, in two dimensions, and by the sphere, in three dimensions. In addition to what is already known of those lines, the author points out that when a cylinder moves through still-water, the orbits of each particle of water is one loop of an elastic curve. The profile of waves has been used with success in practice as water-lines for ships, first, by Mr. Scott Russell (for the explanation of whose system the author refers to the *Transactions* of the Institution of Naval Architects for 1860-61-62), and

afterwards by others. As to the frictional resistance of vessels having such lines, the author refers to his own papers; one read to the British Association, in 1861, and printed in various engineering journals, and another read to the Royal Society, in 1862, and printed in the *Philosophical Transactions*. The author proceeds to investigate and explain the properties of a class of water-lines, comprising an endless variety of forms and proportions. In each series of such lines, the primitive water-line is a particular sort of oval, characterized by this property, that the ordinate at any point of the oval is proportional to the angle between two lines drawn from that point to two foci. Ovals of this class differ from ellipses, in being considerably fuller at the ends and flatter at the sides. The length of the oval may bear any proportion to its breadth, from equality (when the oval becomes a circle) to infinity. Each oval generates an endless series of water-lines, which become sharper in figure as they are further from the oval. In each of those derived lines, the excess of the ordinate at a given point above a certain minimum value, is proportional to the angle between a pair of lines drawn from that point to the two foci. There is thus an endless series of ovals, each generating an endless series of water-lines; and amongst those figures, a continuous or "fair" curve can always be found, combining any proportion of length to breadth from equality to infinity, with any degree of fulness or fineness of entrance, from absolute bluffness to a knife-edge. The lines thus obtained present striking likenesses to those at which naval architects have arrived through practical experience; and every successful model in existing vessels can be closely imitated by means of them, from a Dutch galliot to a racing-boat. Any series of water-lines, including the primitive oval, are easily and quickly constructed with the ruler and compasses. The following curves, traversing certain important points in the water-lines, are exactly similar for all water-lines of this class, and are easily and quickly constructed with the compasses. One is a hyperbola, which traverses all the points at which the motion of the particles, in still-water, is at right angles to the water-lines. The other consists of the two branches of a curve of the fourth order. One of those branches traverses a series of points, at each of which the velocity of gliding of the particles of water along the water-line is less than at any other point on the same water-line. The other branch traverses a series of points, at each of which the velocity of gliding is greater than at any other point on the same water-line. The transverse axis of co-ordinates, so far as it lies within this branch, traverses a series of points of minimum velocity of gliding; from its intersection with the same branch onwards, it traverses a series of points of maximum velocity of gliding. Every water-line, complete from bow to stern, which passes within the point of intersection of the same branch with the transverse axis has three points of minimum and two of maximum velocity of gliding; while every water-line which passes through or beyond that point has only two points of minimum and one of maximum velocity of gliding. Hence

the latter class of lines causes less commotion in the water than the former. On the water-line which traverses the said point itself, the velocity of gliding changes more gradually than on any other water-line having the same proportion of length to breadth. Water-lines possessing this character can be constructed with any proportion of length to breadth, from $\sqrt{3}$ (which gives an oval) to infinity. The finer of those lines are found to be nearly approximated to by wave-lines, but are less hollow at the bow than wave-lines are. The author shows how horizontal water-lines at the bow, drawn according to this system, may be combined with vertical plane lines of motion for the water at the stern, if desired by the naval architect. In this, as in every system of water-lines, a certain relation (according to a principle first pointed out by Mr. Scott Russell) must be preserved between the form and dimensions of the bow and the maximum speed of the ship, in order that the appreciable resistance may be wholly frictional and proportional to the square of the velocity (as the experimental researches of Mr. J. R. Napier and the author have shown it to be in well-formed ships), and may not be augmented by terms increasing as the fourth and higher powers of the velocity, through the action of vertical disturbances of the water.

A discussion ensued, in which Messrs. J. Scott Russell, T. Webster, J. R. Napier, and Prof. Pole took part.

Proceedings British Association.

For the Journal of the Franklin Institute.

Atmospheric Pressure as a Mechanical Power.

In a recent article in the *Journal*, on the use of Air as a motive power in cities, reference is made to various processes for producing a vacuum under a piston, and the inference drawn that they are all too costly, too slow, or, in other respects unsuited for obtaining a popular working force from the pressure of the atmosphere. Of others not mentioned, there is one that may be worth suggesting.

I believe there are no forces but what are designed to be employed in the arts: that all, known or unknown, are to be brought into the service of man; that nature not only provides them, but in her applications of them, is their best expositor, and that whatever she effects for herself with one, we can produce it by the same or analogous results for ourselves. On the present occasion, I would refer to the means by which she disturbs the equilibrium of the atmosphere in the instantaneous condensation of vapor into rain, and the resultant ærial squalls and commotion that prevail in temperate and become so terrific in tropical latitudes. Here we perceive she is doing the very thing we want to do—employing the weight of the atmosphere as an active motive power—neutralizing its influence on one spot and accumulating it on another, by forming a vacuum as it were in a cylinder whose sides pressed together, perform the part of a piston with us. Not a day, probably not an hour, passes, in which these phenomena do not occur in one part of the earth or another.

The fall of rain does not appear to depend on temperature alone.

since it comes down night and day in all weathers; in summer as in winter, and in the warmest climes in actual torrents. The influence of electricity over atmospheric phenomena is universally admitted, and by some, if not by all, meteorologists, it is deemed the *immediate* cause of rain. That tempests, hurricanes, tornadoes, &c., arise from the vacuum thus suddenly produced, is still more generally conceded. They are commonly accompanied with thunder and of brief duration, subsiding as the voids become filled and the equilibrium restored. In some regions where thunder is little known, it is said, there is little rain. Now, why may not artificial clouds of vapor—of low steam in a cylinder—be as quickly collapsed into water by the same means, and vacuities produced to serve our purposes as nature produces them to serve her own? I suppose they may. If some element should be wanting in the process it is our part to supply it. If *air*, for example, be found essential, a limited quantity might be admitted. If the condensation should not be effected as rapidly as anticipated, the area of the piston might be proportionally increased, and so with regard to other points. Electricity, as a science, is in its infancy. It has opened some of Nature's secrets, but they are few compared to those yet to be explained. Among them is the part it plays in the phenomenon in question. If, as is asserted, it causes the aqueous corpuscles suspended in the atmosphere to coalesce and descend, sometimes in drizzle as through the finest cullender, at others in showers of large drops, and again in sheets as if from the bursting of water-spouts, we ought to be able to bring out kindred results by it to establish the theory.

But without reference to any theory, the object is to learn how nature effects those sudden collapsions of vapor. Be the process what it may, mechanical or chemical, or a combination of both—whether clouds surcharged with moisture are discharged by compressure, somewhat as we squeeze a saturated sponge or wring out wet linen, or whether it be, as suspected, an electric talisman that neutralizes the power that keeps the aqueous globulus apart and holds them in suspension; or anything else—when thoroughly known, we can certainly master it sufficiently to work out on smaller scales the same result. If, when developed, it should not be found preferable to processes we have, it is still worth finding out, were it but to determine that fact. But if, on the other hand, it should turn out much better than the best of them—simpler, cheaper, and more prompt, and there should be no obstacles to its general adoption—the benefits it would confer on our species for all time to come, would surpass those of other forces combined, steam included. It would meet almost every call for labor, for domestic and manufacturing dredgery in-doors and out. In a word, I can hardly imagine a nobler acquisition in practical science than the derivation of a general working power from the pressure of the atmosphere. A stronger stimulus to solve a great problem there cannot be.

It is probably in some such indirect way as this that electricity, in one or more of its forms, is to become, if ever, a popular motor, not directly as has so often been attempted and as often failed. Let us use it as Nature does and we are sure to succeed.

On the Proportions of Ships of least Skin Resistance for a given Speed and Displacement. By Prof. RANKINE.

From the London Athenæum, Sept., 1863.

The author referred to a previous paper which he had read to the British Association in 1861, and in which he had stated the results of a theoretical investigation of the "skin-resistance" of ships, and verified those results by a comparison with those of experiments. In the course of that paper he had stated, that the theory gives, for the proportion of length to breadth which produces least skin-resistance with a given displacement and speed, that of *seven* to *one*, nearly. This is the case when the figures and proportions of the cross-sections are given, so that the draft of water bears a fixed proportion to the breadth. But, when the draft of water has a fixed absolute value, the theory gives a somewhat different result; for the proportion of length to breadth which produces the least skin-resistance is found to increase as the draft of water becomes shallower.

Proceedings British Association.

For the Journal of the Franklin Institute.

On the Integral of $\frac{dz^2}{dx^2} = \frac{8w}{R} z^{\frac{3}{2}} + c.$

By DE VOLSON WOOD. Prof. of Civ. Eng. Univ. of Mich.

In an article on "*Beams of Uniform Strength*," published in Vol. xlii, third series, page 110 of this *Journal*, will be found the equation at the head of this article in which c is the constant of integration. I raised the query whether it could be integrated in finite terms. Upon a recent examination of it, I find that it may be integrated by means of the higher transcendentals, in the following way:

We have $$dx = \frac{dz}{\sqrt{c + \frac{8w}{R} z^{\frac{3}{2}}}} = \sqrt{\frac{R}{8w}} \; \frac{dz}{\sqrt{c_1^3 + z^3}} \quad . \quad . \quad (1)$$

where $c_1^3 = \frac{R\,c}{8w}$.

Let $z^{\frac{3}{2}} = -u^2$ and the equation becomes

$$dx = -\frac{2}{3c_1} \sqrt{\frac{R}{8w}} \; \frac{u^{\frac{1}{2}}\,du}{\sqrt{1 - \frac{u^4}{c_1^3}}} \quad . \quad . \quad . \quad (2)$$

Now let $$\frac{u}{c_1} = \left(1 - y^2\right)^{\frac{3}{2}} \quad \therefore \quad u^{\frac{1}{2}} = c_1^{\frac{1}{2}} \left(1 - y^2\right)^{\frac{1}{2}}$$

$$du = \tfrac{3}{2}(1 - y^2)^{\frac{1}{2}} dy$$

(This y is not the depth of the beam as used in the problem.)

These substituted in the preceding equation gives

$$dx = -c^{\frac{1}{2}} \frac{\sqrt{R}}{2w} \frac{1-y^2}{\sqrt{3-3y^2+y^4}}\, dy \quad . \quad . \quad (3)$$

As the solution of this, in finite form, involves the use of *elliptic functions*—a branch of mathematics extensively studied by comparatively few students—I shall only indicate the steps.

Equation (3) is in a convenient form to put in ordinary form for elliptic functions. See *Le Gendre's Elliptique Fonctions*, page 9, 6th paragraph. The roots of the denominator are all imaginary; hence it comes under the first case. This case in the form of Equation (3) is given on page 55 of Le Gendre.

The form is

$$x = \int \frac{(f+gy^2)\, dy}{\sqrt{a^2+2aby^2\cos.\theta+b^2y^4}} \quad . \quad . \quad . \quad . \quad (4)$$

The integral of which is given on page 56, and is

$$= \frac{fb+ga}{b\sqrt{ab}} \mathbf{F}_{(c,\varphi)} - \frac{2ga}{b\sqrt{ab}} \mathbf{E}_{(c,\varphi)} \quad . \quad . \quad . \quad (5)$$

Equation (3) compared with (5) gives

$$f=1 \quad a^2=3 \quad \cos.\theta = -\tfrac{1}{2}\sqrt{3}$$
$$g=-1 \quad b^2=1 \quad \therefore \quad \theta = 120°,$$

which substituted in (5) gives

$$x = -\left(\frac{R\,c}{8w}\right)^{\frac{1}{6}} \left(\frac{R}{2w}\right)^{\frac{1}{2}} \left[\frac{1-\sqrt{3}}{\sqrt[4]{3}} \mathbf{F}_{(c,\varphi)} + 2\sqrt[4]{3}\, \mathbf{E}_{(c,\varphi)}\right] \quad (6)$$

We also have $c = \sin.\frac{1}{2}\varphi$.

$$\cos.^2\varphi = \frac{-by^2 - a\cos.\theta + \sqrt{a^2+2aby^2\cos.\theta+b^2y^4}}{2a\sin.\frac{1}{2}\theta} \quad . \quad . \quad (7)$$

$$\therefore \quad \varphi = 0 \text{ for } y = 0$$

Equation (6) gives $x = 0$ for $\varphi = 0$ as it showed, since x and y are both zero at the origin.

To construct the curve we may assume y, and by the relations given above, find u and $z^{\frac{1}{2}}$, which last value will be the ordinate. To find the corresponding abscissa, substitute the assumed value of y in equation (7) and find φ, and then Table IX, Vol. II, Le Gendre, will give $\mathbf{F}_{(c,\varphi)}$ and $\mathbf{E}_{(c,\varphi)}$ which in equation (6) will give φ.

It is difficult to find c, the first constant of integration, because its value is contained in a transcendental function.

This solution induces me to make a remark upon the integration of expressions.

We know that the cases which will admit of integration in finite form are comparatively few. Any known function may be differentiated (or disintegrated), and the result is *typical* of the infinitessimal-elements which result from the function.

But it is not *generally* possible to pass from the differential to the integral, because we do not know the *form* of the function which will give the *form* of the given differential. It is generally necessary to have the function (and this is known first) and the typical infinitessimal-element before we can deduce rules for passing from the latter to the former. Thus we know how to integrate sin. $x\,dx$, because we know the form of the function from which it is derived, viz: $-\cos. x$; but we cannot integrate log. $x\,dx$ (in finite form), because we do not know the form of the function from which it is derived. To integrate it we must have some transcendental function of higher order, which, in the course of time, may possibly become known.

But all transcendental functions do not require transcendentals of a higher order. Thus the integral of the trigonometrical functions, sin. $x\,dx$, tan. $x\,dx$, sec. $x\,dx$, &c., are expressed in other trigonometrical functions. Still it is more generally the case that integration raises a function to a higher transcendental, and the integral of this higher one demands still higher.

Thus $\int \frac{dx}{\sqrt{1-x^2}} = \sin.^{-1} x$; but $\sin.^{-1} x\,dx$ is not integrable.

$\int \frac{\cos. x\,dx}{\sin. x} = \log._e \sin. x$, but $\log._e \sin. x\,dx$ is not integrable.

$\int \frac{2\,dx}{x^3} = \frac{-1}{x^2}$, and $\int \frac{-dx}{x^2} = \frac{1}{x}$, and $\int \frac{dx}{x} = \log. x$, but $\log. x\,dx$ is not integrable.

It is sometimes the case that algebraic expressions may be transformed so that their integral can be expressed in known transcedentals. Such is the case with the expression which forms the subject of this article. All differential expressions may be regarded as being derived from some function.

Hence, from this brief view of the subject, we infer, that if we knew all possible forms of transcendentals, we might integrate all differential expressions.

On a Mercurial Air Pump. By Mr. J Swan.

From the London Athenæum, Sept., 1863.

In general arrangement and appearance this instrument resembles a barometer, with very large lower reservoir, having an inlet and outlet pipe at the top of this, each provided with a stop-cock; and with the upper part of the barometer tube very greatly enlarged—in fact, a reservoir at the top, and a reservoir at the bottom. The upper reservoir, termed a vacuum-chamber, is surmounted by a ball-valve opening outward, and has also a tube with a stop-cock communicating with the vessel to be exhausted. The vacuum-chamber, tube, and a portion of the lower reservoir are, in the normal condition of the apparatus, to to be occupied by mercury. The remaining space within the lower

reservoir is to be filled with water, which may be separated from the mercury by a caoutchouc bag, tied on the lower end of the tube containing the mercurial column. The inlet pipe entering the lower reservoir is to be connected with town water-pipes or a force pump. The working of the pump is effected by opening the outlet-pipe so as to permit the mercury to vacate the vacuum-chamber, and descend to the barometric level, displacing the water from the lower reservoir. Then the vacuum formed having been taken advantage of by opening the communication between the vacuum-chamber and the vessel to be exhausted, the original condition of things is restored by closing the outlet-pipe of the lower reservoir, and opening the inlet, so as to supply water at a high pressure, which will force the mercury to re-occupy the vacuum-chamber, the valve at the top allowing the exit of its more or less attenuated gaseous contents. This process, being frequently repeated, will, no doubt, give a very perfect vacuum, as there is no obstruction, of the nature of a valve, between the vacuum-chamber and the vessel to be exhausted. This air pump was said to be specially adapted for the exhaustion of small vessels. It was proposed that the instrument should be made entirely of wrought iron ; among its advantages were small cost and simplicity, its efficiency not depending upon fine worknamship.

Proceedings British Association.

Locomotive Construction.

From the Lond. Mechanics' Magazine, Sept., 1863.

Notwithstanding the dictum contained in Clark's "Railway Machinery," we cannot regard the link motion as otherwise than imperfect. Its comparative excellence we admit ; but with the growing tendency for higher pressures and early cut-off, its defects become day by day more prominent. In order to maintain anything like a full pressure on a piston, moving at 800 or 1000 feet per minute—a speed frequently reached in express engines—it is essential that all passages leading to the cylinder should not only be short, direct, and of large area, but that they should be opened and closed with a velocity proportionate to the speed of the piston. Locomotives are seldom worked in the central notches, except when running fast. The travel of the valve is then shortened, and the ports are not only reduced in area, but opened and closed with a tardiness, which greatly militates against the advantage to be derived from an early cut-off, diagrams taken at high speed showing a very remarkable loss of pressure as the piston pursues its course through the cylinder. Steam is estimated to flow into a vacuum with a velocity equal to that due to a body of the same density, falling through a space equal to the height of a column of steam of the given pressure. By this rule, steam of 120 lbs. pressure would flow into a vacuum at about 2079 feet per second ; but the difference between the velocities of any two pressures, is the velocity with which steam would flow into steam of a lower pressure. At the commencement of a stroke, or rather at the moment when the valve first

opens, the pressure within the cylinder is comparatively trifling, steam then enters with great velocity; once, however, the difference in the densities of the steam in the boiler and that in cylinders ceases to be well defined, steam passes very sluggishly from the former to the latter, and is little able to overcome the resistance offered by long curved passages and the contracted areas of the steam ports. It is very unusual, in consequence, to maintain more than 70 lbs. in the cylinder at high speed, indicator diagrams falling at once on the commencement of the stroke, long before the steam is really cut off. The analization of such diagrams is not easy, as it is impossible to tell, without setting out and measuring the valve gear, when the valve really closed. Theoretically, the ports should be extremely short, straight passages, opening directly from the valve-seat into the cylinder. The great size of the valve required to suit such an arrangement has hitherto precluded its adoption. Mr. Clark gives us good reason to believe that as much as 25-horse power is frequently expended in working valves as it is—a positive waste of power which it would be very injudicious to add to. If, however, the valves are properly balanced, there is nothing to prevent the employment of any size deemed most desirable; and if we are to adhere to the link and eccentrics, the sooner we have a large valve with a long throw, and great lap, the better. We illustrate this week a form of balance-valve, which, although recently patented here, has been worked for some time in America with considerable success. Plainmaison's slide-valves have been adopted on the Chemin de Fer du Nord since the year 1861 with excellent results both in the Crampton express and Engerth goods engines. Railway companies don't like change, however; and the general introduction of the balance-valve is, here at least, apparently as far off as ever.

Quitting the subject of valves, and resuming the consideration of the means by which they are put in motion, we find existing arrangements, lauded for simplicity which they do not really possess. The link motion, consisting as it does of two eccentrics with their rods, straps, pins, &c.; a link often built up of many pieces; and a rocking-shaft with balance weights or springs; is really the most complex part of the engine. Its expense is very considerable at first; and from the rapid wear to which it is exposed, and the nice adjustment which it must preserve, its maintenance forms a large item in the working expenses of the locomotive. We are well aware that this must be a distinguishing characteristic of any valve gear whatever; but we believe that other arrangements not a whit more complicated, will give better results. The mere fact of such a piece of machinery, delicate and finely wrought, answering its purpose so well, should rather encourage us in searching for a substitute which, not more simple, perhaps, would regulate the admission of steam to and its exit from the cylinders after a fashion approaching more nearly to theoretical excellence. Complexity is in itself no evidence of erroneous design. It only becomes reprehensible when it is introduced unnecessarily. In the construction ot machinery, the end usually sanctifies the means; and there is no reason

that a valve gear may not be very excellent, and very complex as well. In America, the use of the separate cut-off was long adhered to, and is even still held in high favor by many builders. At least one locomotive in the great Exhibition last year was so fitted, and it seems likely enough that its general adoption is not far distant. The variation in the lead, when the reversing lever is in different notches, is not the least objection to the link motion. The setting of valves is in consequence a positive science, and one understood or at least practised, only recently. A few years ago it was quite exceptional to meet with a locomotive which "beat" equally. Even yet there is great room for improvement on most of our great railway lines.

The question of balance weights, at one time considered definitively settled, seems likely to be re-opened. It is extremely doubtful that it is good practice to perfectly balance the reciprocating parts of a locomotive. One locomotive superintendent has removed three-eighths of the accurate counterpoise from his engines, with manifest advantage. The solution of the problem lies, we fancy, in the fact that the pressure on the piston does not accurately represent that on the crank-pin, when the engine is in motion, because it is modified more or less by the momentum of the piston-rod, and connecting-rod—to such an extent, indeed, in some cases, that the strain on the crank-pin is much greater near the termination of a stroke than at its commencement, although the steam is early cut off. As the equalization of the impelling force on the crank-pin is extremely desirable, tending as it does to the steadiness of the entire machine, it is not improbable that a heavy cross-head, piston, and piston-rod may be better for high-speed locomotives cutting off very early, than those of a lighter construction. There can be no doubt, however, that the wheels must be accurately balanced, and this rule is seldom or never disputed. In conducting experiments on the subject, care must be taken to distinguish between the conditions under which an engine is tried in the shed, and those under which it performs its work on the road.

There is little tendency to alter the practice which deems a single pair of drivers sufficient for express engines. Locomotives intended for high speeds seldom or never are burdened with heavy trains, and with rails in good order they manage to proceed well enough, but, unfortunately, not without doing great mischief to the permanent way, in consequence of the excessive loads placed on the drivers to secure adhesion. Still there seems to be much weight in the arguments which are urged against coupling wheels over 7 feet in diameter, which make 270 revolutions betimes in the minute. The momentum of an 8-foot side-rod at such a pace would be something tremendous, and its fracture would lead to fearful results. For ordinary passenger trains there is no excuse for limiting the number of drivers to two, and coupled engines are rapidly getting into favor for this kind of work. For æsthetical as well as mechanical reasons, the second pair of driving-wheels should be placed behind the fire-box, not forward. If inside cylinders are adopted, the latter position throws all the work out of

the horizontal line, and entails many difficulties with the smoke-box and framing. A few large engines of this class are doing good service on the North-Western, between Birmingham and Stafford. The driving-wheels are, we believe, 6 feet in diameter, and hence the cylinders do not come inconveniently near the ground.

Steel tyres make their way rapidly into favor with locomotive superintendents, while the civil engineer regards them with unmitigated disgust, from their destructive effort on permanent way. Six or seven tons on a single wheel was, however, more than any iron tyre, possessing toughness enough to be safe, could bear without spreading; and to the employment of hard irons which were resorted to as a remedy, may be attributed many of the accidents once so prevalent from the fracture of tyres. Railway companies have found it much to their advantage to purchase rails honestly made of good iron properly worked, instead of cheaper brands which proved utterly worthless. Steel tyres are not very injurious to such rails; still, a softer material is better for adhesion, cheaper to work, and perhaps safer, in some respects, than steel. If a tyre could be made, one with the wheel-rim proper, there is no doubt that its durability would be considerably increased; not only would its resistance to spreading be greater, but the shocks and vibrations to which it is exposed would be transmitted to the entire mass of the wheel, instead of being more or less retained in the tyre. Under the present system, the tyre is exposed to a treatment nearly similar to that which it received in the rolling mill which gave it existence, the interior being nearly as much injured by the wheel-rim, as the exterior is by the rail. Mr. G. S. Griggs, of the Boston and Providence Railroad, U. S., many years ago, set all his tyres on wood to avoid this action. The rims of the wheels are made with dove-tailed recesses all round, running in the direction of the axle. Into these recesses hard wood-blocks, thoroughly dried, are firmly fixed, with the grain running in the direction of the groove. The tyres are then shrunk on, resting wholly on the wood, which stands, say, an eighth of an inch or less above the surface of the wheel-rim. Mr. B. Adams has brought out a far more elegant arrangement here. He introduces a continuous hoop spring, fitting within an internal groove in the tyre, between it and the wheel. Two of these hoops are, we believe, employed at present, each about one-third of an inch thick and 3½ inches wide. The wheel-rim is turned slightly convex, and rests on the hoops, which of course surround it. Experiments conducted on the St. Helen's Railway, Lancashire, show that Staffordshire tyres, fitted to wheels on this system, have given first-rate results when put in competition with Krupp's steel, Swedish, and Hood and Cooper's best iron, fitted in the common way. Krupp's tyres have run 40,873 miles, Hood and Cooper's 20,798, Swedish 34,006, without requiring turning up, as an average mileage; while Staffordshire tyres, fitted on springs, have run 55,138 miles, remaining in excellent condition. The engines had all 4 feet 6 inch wheels, except the last, which had 4 feet, and their weights varied from 19 tons 15 cwt., on Krupp's, to 26 tons

6 cwt. on Hood and Cooper's, 23 tons 14 cwt. on Swedish, and 21 tons on Mr. Adams' tyres. The saving to the rails must be considerable, for tyres can only be worn out at the expense of the rails. This same question of tyres nearly concerns the prosperity of railway companies. The maintenance of the permanent way is one of the heaviest items of expenditure which they have to encounter; and as the destroying element is found in the wheels of the locomotive, every improvement of which they are susceptible should be applied to them, without regard to the primary outlay, which is certain to repay itself a hundredfold.

Report by the Committee appointed to Investigate some Improvements in Gun Cotton.

From the London Athenæum, Sept., 1863.

The President said, the first business this morning was to receive an exceedingly important "Report by the Committee appointed to investigate some Improvements in Gun Cotton." It was a committee formed partly of members of the Mechanical Section and partly of members of the Chemical Section. The chemical part would chiefly occupy their attention.

Dr. Gladstone read the Chemical portion of the Report.—Since the invention of gun cotton by Prof. Schönbein, the thoughts of many have been directed to its application to warlike purposes. Many trials and experiments have been made, especially by the French; but such serious difficulties presented themselves that the idea seemed abandoned in every country but one, Austria. From time to time accounts reached England of its partial adoption in the Austrian service, though no explanation was afforded of the mode in which the difficulties had been overcome, or the extent to which the attempts had been successful. The committee, however, have been put in possession of the fullest information from two sources—Prof. Abel, chemist to the War Department, and Baron W. von Lenk, Major-General in the Austrian Artillery, the inventors of the system. Prof. Abel, by permission of the authorities, communicated to the Committee the information given by the Austrian Government to our Government, and also the results of his own elaborate experiments. General von Lenk, on the invitation of the Committee, by permission of the Austrian Government, paid a visit to this country, to give every information in his power on the subject, and brought over drawings and samples from the Imperial factory. The following is a summary of the most important points:—As to the chemical nature of the material, von Lenk's gun cotton differs from the gun cotton generally made, in its complete conversion into a uniform chemical compound. It is well known to chemists that, when cotton is treated with mixtures of strong nitric and sulphuric acids, compounds may be obtained varying considerably in composition, though they all contain elements of the nitric acid and are all explosive. The most complete combination (or product of substitution) is that de-

scribed by M. Hadon as $C_{36}\ H_{21}\ (9\ NO_4)\ O_{30}$, which is identical with that termed by the Austrian chemists Trinitrocellulose, $C_{12}\ H_7\ (3\ NO_4)\ O_{10}$. This is of no use whatever for the making of collodion; but it is von Lenk's gun cotton, and he secures its production by several precautions, of which the most important are the cleansing and perfect desiccation of the cotton as a preliminary to its immersion in the acids—the employment of the strongest acids attainable in commerce—the steeping of the cotton in a fresh strong mixture of the acids after its first immersion and consequent imperfect conversion into gun cotton,—the continuance of this steeping for forty-eight hours. Equally necessary is the thorough purification of the gun cotton so produced from every trace of free acid. This is secured exclusively by its being washed in a stream of water for several weeks. These prolonged processes are absolutely necessary. It seems mainly from the want of these precautions that the French were not successful. From the evidence before the Committee it appears that this nitro compound, when thoroughly free from acid, is not liable to some of the objections which have been urged against that compound usually experimented upon as gun cotton. It seems to have a marked advantage in stability over all other forms of gun cotton that have been proposed. It has been kept unaltered for fifteen years; it does not become ignited till raised to a temperature of 136° C. (277° Fahr.); it is but slightly hygroscopic, and when exploded in a confined space, is almost entirely free from ash. There is one part of the process not yet alluded to, and the value of which is more open to doubt—the treatment of the gun cotton with a solution of silicate of potash commonly called water glass. Prof. Abel and the Austrian chemists think lightly of it; but von Lenk considers that the amount of silica set free on the cotton by the carbonic acid of the atmosphere is really of service in retarding the combustion. He adds, that some of the gun cotton made at the Imperial factory has not been silicated at all, and some imperfectly; but when the process has been thoroughly performed, he finds that the gun cotton has increased permanently about 3 per cent. in weight. Much apprehension has been felt about the effect of the gases produced by the explosion of gun cotton upon those exposed to its action. It has been stated that both nitrous fumes and prussic acid are among these gases, and that the one would corrode the gun and the other poison the artilleryman. Now, though it is true that from some kinds of gun cotton, or by some methods of decomposition, one or both of these gases may be produced, the results of the explosion of the Austrian gun cotton without access of air are found by Karolys to contain neither of them, but to consist of nitrogen, carbonic acid, carbonic oxide, water, and a little hydrogen and light carburetted hydrogen. These are comparatively innocuous; and it is distinctly in evidence that, practically, the gun is less injured by repeated charges of gun cotton than of gunpowder, and that the men in casemates suffer less from its fumes. It seems a disadvantage of this material as compared with gunpowder that it explodes at a temperature of 277° Fahr.; but against the greater liability to accidents from this course may be set the almost

impossibility of explosion during the process of manufacture, since the gun cotton is always immersed in liquid, except in the final drying.* Again, if it should be considered advisable at any time, it may be stored in water, and only dried in small quantities as required for use. The fact that gun cotton is not injured by damp like gunpowder is, indeed, one of its recommendations, while a still more important chemical advantage which it possesses arises from its being perfectly resolved into gases on explosion; so that there is no smoke to obscure the sight of the soldier who is firing or to point out his position to the enemy, and no residuum left in the gun, to be got rid of before another charge can be introduced.

* In ten years' experience it is proved that this temperature is sufficiently high to insure safety of manipulation: 277° Fahr. is an artificial temperature, and artificial temperatures accidentally produced are generally high enough to ignite gunpowder. The greater liability to accident from this cause can, therefore, scarcely be admitted.

Gun Cotton as an Explosive Agent.

From the London Practical Mechanic's Journal, October, 1863.

A Joint Committee of the British Association, emanating from two Sections, the Chemical and the Mechanical, was formed at the Cambridge Meeting, for the purpose of inquiring into the state of knowledge of gun cotton as an explosive agent. Wisely so; for while we in England have laid to for years, since the accident at the Dartford Powder Mills, early in the history of the discovery, continental nations have been steadily pursuing the subject, and with a very remarkable success; the Austrian Government having at this moment no less than *thirty-six batteries* of field artillery completely equipped for gun cotton ammunition.

Great interest was therefore excited at Newcastle at the late meeting of the British Association, by the presentation of the report of the above committee, which was read in both sections, but we cannot say discussed. The report on Baron Lenk's gun cotton made to the Austrian Government is a highly important document, and having through the kindness of Dr. Schneider procured a copy, we present it *in extenso* to our readers in English.

The report of the chemical side of the committee was also important, and a very long statement of experimental trials and technical details as to the best methods of manufacture on the Arsenal scale, and on the properties of gun cotton as a practical form of ammunition, the modes of preserving, &c., &c., read by Dr. Abel, the chemist to the War Department, were also highly important productions, which will appear in the forthcoming volume of reports of the Association. We cannot say quite as much for the mechanical side of the joint committee, read by Mr. John Scott Russell, for although comprising some interesting and curious discussion, it appeared to us to have been framed in a good deal of ignorance of what had been ascertained experimentally, and

printed several years since by French officers and philosophers, and more especially by General Piobert and Colonel Mallet of the French Artillery on the subject of the Dynamic conditions of gun cotton explosion.

Baron Lenk has added in several respects to our prior knowledge, in the specialities of preparation of gun cotton, but his most decisive advance has been, his placing in a very clear light, if not his discovering the highly important fact, that the rapidity of the explosion of gun cotton, and with that, its *pouvoir brisánte*, may be modified to any extent by the amount of compression and the form of texture (so to say) given to it in the cartridge.

We shall return to the subject, and meanwhile may refer our readers for a *resumé* of Colonel Mallet's and General Piobert's investigations, and in general for a pretty clear view of the ballistics of the subject, to chapter 29, p. 127, *et seq.* of Mr. R. Mallet's work on Artillery.

REPORT ON BARON LENK'S GUN COTTON, BY PROFESSORS DR. REDTENBACHER, DR. SCHRÖTTER, AND DR. SCHNEIDER.

To His Excellency Field-Marshal Johann Freiherr Kempen von Fichtenstamm. President of the Royal Imperial Commission on Gun Cotton, June, 1863.

In accordance with your Excellency's wish, the undersigned submit the following opinions relative to the objections urged against the adoption of gun cotton for our purposes.

Introduction.—It is not possible within the limits of the present report to discuss all the various products which, since the discovery by Schonbein, in 1846, of a method of chemical treatment whereby cotton might be rendered explosive, have been brought forward, examined, and applied under the various names of "Gun Cotton," "Pyroxlyn," "Fulmi-coton," "Nitro cellulose," &c.,—or at any rate to do more than mention such as have been brought under our notice in the course of experiments performed by us with Baron Lenk's gun cotton.

It is true that gun cotton has frequently and by various persons been manufactured by modifications of one of the two following processes, viz:—

(1) By acting on cotton with mixtures of nitric and sulphuric acid.
(2) By acting on cotton with mixtures of saltpetre and sulphuric acid.

These two general processes have been so much varied in detail by different experiments, that the resulting specimens of gun cotton must necessarily have been most diverse in quality. The variations of detail may be classified as follows, viz:—

(1) Variations as to strength of acids.
(2) Variations as to the conditions of mingling the acids.
(3) Variations as to duration of chemical action.
(4) Variations as to temperature.
(5) Variations as to the removal of free acid from the resulting gun cotton.

These variable conditions being taken into consideration, it is no longer a matter of surprise that even the chemical composition of gun cotton has been differently stated by different authorities. Accordingly whilst one set of chemists, in explaining the *rationale* of action whereby ordinary cotton is changed into gun cotton, refer the change to a substitution of one equivalent of hyponitric acid for three equivalents of hydrogen in the original cotton; another set affirm that four equivalents represent the hydrogen exchanged; and yet other chemists, five equivalents. In addition to these three definite compounds, various analyses have testified to an infinity of secondary bodies, the result of mechanical mixtures.

Unforeseen explosions of gun cotton occurring without any known cause, and assumed to have been the result either of spontaneous combustion, or of some unimportant elevation of temperature, as up to 50° or 60° C., have frequently been chronicled in the short history of this substance; whilst on the other hand, reliable authorities have fixed the exploding temperature between 130° and 160° C.,—another proof as to the variety of materials operated upon on a small scale. The chief experiments relative to gun cotton have been made by chemists upon small portions, one pound being looked upon as a considerable quantity. Results based on such data may be considered on a par with general conclusions as to the properties of gunpowder founded upon experiments with a mixture by hand of charcoal, sulphur, and nitre, in quantities yielding a pound weight aggregate.

Chemical changes involved in the manufacture of gun cotton.—§ 2. The fact should be borne in mind, that the changes which cotton undergoes in its treatment with nitric and sulphuric acids conjointly, are not alone peculiar to cotton and other vegetable fibre, but that a great number of organic bodies are amenable to a corresponding change if they be similarly treated. The exact grade of mutation which any particular organic substance may undergo when treated as above will differ, however, according to circumstances. Even if, as a rule, we assume that for every equivalent of water displaced, an equivalent of nitric acid is appropriated—or, what amounts to the same thing, if the assumption be that every single equivalent of hyponitric acid exchanges with a corresponding equivalent of hydrogen—still variations of result may be accounted for by reference to the modifying conditions already indicated. However, the general deductions may be arrived at, that the amount of hyponitric acid appropriated is directly as the amount of hydrogen lost.

Possibly, the results obtained by chemists on the small scale, using small amounts of cotton and relatively large amounts of acid, may not be identical in composition with corresponding results of large scale operations: time in both cases being constant. It may also be fairly assumed that certain portions of the original cotton may escape nitrification, wholly or partially. These suggestions tend to show the little value that can justly be attached to past experience with gun cotton, if cited in reference to the specific gun cotton of Baron Lenk.

Experiments by the French.—§ 3. An extensive series of experiments with gun cotton must, however, not be passed over; the material having been produced commercially on a large scale, and the investigation moreover conducted by military and scientific authorities. A record of these experiments may be seen in Berthier's "Mémoire de l'Artillerie," Paris, Bathelier, 1852.

Immediately after the discovery of gun cotton in 1846, the French Minister appointed a commission of inquiry relative to it.

For a period of six years this commission prosecuted its investigations, and the results are printed in the pamphlet above mentioned.

These experiments were conducted on a large scale; five tons of gun cotton being manufactured. This commission instituted the most searching inquiries relative to every possible ballistic and other military use to which gun cotton could be applied. No less than thirty tabulated digests resulted from the labors of this French committee.

Experiments so seemingly exhaustive might reasonably prompt the assumption that no point relative to gun cotton and its application had remained undetermined. It might seem that the subject of gun cotton was definitely set aside after the decisive verdict which the following quotation records:—

"Dans l'état actuel, il n'y a pas lieu de continuer les expériences au point de vue de leur emploi dans les armes de guerre."

Perusal of the report leaves no doubt either as to the pertinence of questions raised, or the intelligence manifested in the corresponding replies.

The French neglected to ascertain the true composition of the cotton.—One point, however, was lost sight of by the French commission, namely the precise composition of the gun cotton operated upon. On this point the commissioners are silent: hence the question, *whether one and the same chemical compound formed the subject of every experiment in the series*, was never raised. The report throughout is based on the assumption that identical methods of treatment must yield identical results; that no analysis was required; that practice in firing supplied the *ultima ratio;* and lastly, that the results of explosion were referable to chemical composition wholly and absolutely. The first proposition is usually, but not *invariably* true, as every chemist knows.

Minor circumstances frequently influence the result of chemical energy, though primary conditions remain unchanged. Chemists sometimes, heeding these primary conditions only, imagine they have continued to do the same thing and to achieve the same result; whereas different acts have been performed, and different results accomplished. This has happened in prosecuting the manufacture of gun cotton, up to the experiments of Baron Lenk. What *may* take place during the change of ordinary cotton into gun cotton, under different conditions, can be thus expressed. The cellulose (matter of cotton) may yield up successive increments of hydrogen, to be replaced by hyponitric acid, according as the acid bath employed varies as to relative bulk, and the

time of action varies. One equivalent of hydrogen is removable more easily than two, two than three, &c., &c.

In this way, not only may specimens of gun cotton (as commonly prepared) be made up of variable mechanical mixtures, of every chemical result possible under the circumstances, but the series may be still further extended by the interpolation of material upon which no chemical action has been exerted. Hence may be deduced a most important distinction between the French gun cotton and that of Baron Lenk.

Difference between the French gun cotton and Baron Lenk's.—According to the method pursued by the French Commission, the raw cotton was immersed in the acid mixture for one hour.

Baron Lenk leaves his cotton forty-eight hours in the acid bath.

The French cotton was afterwards dipped in running water for an hour or an hour and a half.

Baron Lenk's gun cotton lies four, six, or eight weeks in a stream.

The French cotton had after washing, so much free acid left, that wood-ash ley (a solution of carbonate of potash, therefore,) was neutralized by contact with it, and after long use, became sour.

Baron Lenk's cotton is so freed from acid by long immersion, that a two per cent. solution of potash, in which two cwt. of gun cotton had been boiled, had lost none of its alkaline properties; that is to say, that the cotton was completely free from acids, as experiments wholly accordant with those of the Imperial (Austrian) Engineers' Committee fully demonstrated. The French gun cotton having been prepared in a manner so different, it must necessarily have had a different composition to that of Baron Lenk's; hence it is clear that the French experimental results cannot, without considerable reserve, be accepted as precedents.

Lenk's cotton is Tri-nitro Cellulose and uniformly composed.—It manifested no inconsiderable amount of confidence on the part of Baron Lenk, when the French experiments were known to him, that he did not give up the gun cotton altogether; and he can only have been supported by the conviction based on a thoroughly grounded study of the entire process.

Baron Lenk calls the Hirtenberg cotton (and with full right) his cotton, as he prepares it by one constant, definite, and unvarying process.

Baron Lenk takes the strongest preparation of acid, one part nitric acid to three parts sulphuric acid; he impregnates a spun thread of cotton in a boiling solution of potash thoroughly, and leaves the acids to act cold upon the cotton during forty-eight hours.

These details of manufacture are all important; and the resulting cotton is also most convenient for the subsequent process of freeing from acid, drying, and working up; whilst during the time employed, the three most easily removed hydrogen equivalents of the cellulose are completely replaced by hyponitric acid, and during this time the action takes place through the body of the cotton uniformly, so that no isolated portions are less azotized than others; nor if properly

conducted, is any portion too highly azotized; in fact, it can be demonstrated that the Austrian gun cotton contains three easily-removed equivalents of hydrogen.

7. *Analysis.*—This is demonstrated by the recorded analysis of the Austrian Imperial Engineers' Committee, 1861 (vol. i part 1, p. 21), wherein it is shown that Lenk gun cotton is almost wholly composed of tri-nitro cellulose.

ANALYSIS OF AUSTRIAN GUN COTTON.

Laboratory of Engineers' Committee, 1861.

In 100 parts,	Tri-nitro Cellulose calculated.	No. 4.	Original Cotton.
Carbon,	24·3	25·1	
Hydrogen,	2·3	3.0	

University Laboratory, 1863.

No. 3. 1856.		No. 6. 1860.		No. 14. 1862.			Di-nitro Cellulose.
1	2	1	2	1	2	3	
24·4	24·5	24·6	24·2	23·6	23·9	24·1	28·6
2·7	2·8	2·6	2·7	2·6	2·4	2·4	3·2

If this analysis differs somewhat from the theoretical formula of the tri-nitro cellulose, the circumstance must be remembered that cotton is not pure cellulose, but that it consists of long-extended vegetable cellules, in which there is always a little albuminous substance containing over 50 per cent. carbon, and 7 per cent. hydrogen, the presence of which even in such quantities easily increases the per centage of carbon and hydrogen.

The treatment with soluble glass has no influence on Baron Lenk's gun cotton, it being previously free from acids.

Gun Cotton is always put into comparison as an explosive compound with gunpowder; but it must be remembered that one of the component parts of gunpowder—charcoal—is most irregular in quality, especially where the primitive method of preparing it is followed. Still in theoretical disquisitions upon gunpowder, charcoal is taken into account as pure carbon.

Bunsen has so treated the charcoal in his experiments with Berne powder and Austrian army powder at the University Laboratory.

	Berne.	Austrian.	Powder.
Carbon, . .	68·84	81·2	82·9
Hydrogen, . .	3·67	2·8	2·99
Oxygen, . .	27·49	13·6	12·1
Ashes, . .	——	2·4	2.

It is, however, well known that the Austrian charcoal is manufactured at a higher temperature.

The French chemist Violette, who effected the latest improvements of charcoal manufacture, proved a difference in charcoal of eight per cent. in hydrogen, and one per cent. ashes; and the comparative proportions of charcoal of the same wood made at various temperatures varied from 340° to 800° C.

If it be considered that with us the manufacture of gunpowder as well as of charcoal is in the hands of ignorant workmen of the lowest class, who make at one operation, and of the same wood, charcoal at all sorts of temperatures, then the opponents of gun cotton, who imagine they have in powder the perfection of shooting material, are of all persons the least justified in the reproach that Baron Lenk's gun cotton is not uniform in its composition.

This want of uniformity in the composition of powder-charcoal was the origin of the tests by the Berthier process for discovering, before mixing, the component parts of powder, especially the powder-charcoal, by means of the Berthier process or trial, for the purpose of ascertaining its combustive value.

Unalterable quality of the Lenk Gun Cotton.—Even if invariability of composition in respect of gun cotton be conceded, the allegation is made, that if kept for a long time it deteriorates; the ground of this dictum being sought in experiments which show the alteration of the gun cotton to the extent of 100° with regard to litmus paper, and also are assumed to reveal a spontaneously explosive quality. The changes in the Hirtenberg gun cotton can only be ascertained direct by comparison and analysis with other and different samples of gun cotton made on the same day when manufactured, and then by repetition of analysis of the same portions of cotton after one, two, three, or more years; these results finally compared with the first year's analyses: but there exist no such analyses, because they were never made. The opponents of gun cotton themselves have therefore omitted the only true proof of a changeable quality. Such omissions can, nevertheless, be in some degree remedied.

In the magazines of gun cotton at the Neustadter Haide, there are stores of various years.

In the laboratory of the University there are samples of Hirtenberg gun cotton of three several years, which have been examined by the above-named artillery officers, and they have been found not to differ materially in their composition from tri-nitro-cellulose. For instance—

Per Centage.	Tri-Nitro Cellulose.	No. 3 of the year 1860.		No. 6, year 1860.		No. 14, year 1862.		1863.
		1	2	1	2	1	2	3
Carbon, .	24·3	24·4	24·5	24·6	24·2	23·6	23·9	24·1
Hydrogen, .	2·3	2·7	2·8	2·6	2·7	2·6	2·4	2·4

If these results be compared with each other, there can be no right to say that Hirtenberg gun cotton alters by keeping. They agree so far with each other as analyses of the *same material* usually do. It is to be regretted, on this as on many other accounts, that during the last twelve years such analyses were not frequently repeated. If the opponents of gun cotton, in performing an adverse experiment, heat the substance in a test tube up to 100° C., and holding litmus paper over it, deduce from redness of the latter that gun cotton changes after long keeping, they merely prove thereby that gun cotton changes at 100° C. Of an explosive compound, it can only be required that *it shall not deteriorate within certain limits of temperature; a requisition amply fulfilled by Lenk's gun cotton.*

Some varieties of gun cotton, if enclosed together with litmus paper in a tube, often manifest an acid reaction at ordinary temperature. This may arise from various causes. There may exist, for example, free acids. These acids may be the result of nitrogen partly oxidized, and may result from imperfectly worked cotton. This assumption granted, the phenomenon is explained, and the cause is easily avoided.

It may arise from decomposition of the gun cotton, atmospheric dampness having brought about a partial reconstitution of the cellulose.

This assumption granted, the acid reaction just adverted to should be local, affecting the material in particular spots only. This seems a necessary deduction, having regard to the long process of steeping in water to which Lenk's gun cotton is exposed in the course of manufacture. By this steeping process the cotton should otherwise be utterly destroyed.

Possibly the tetra and penta nitro cellulose are more liable to decomposition; but only traces of these bodies are to be found in Lenk's gun cotton, as experiment amply demonstrates. Were it otherwise, analyses should make known (which they do not) a deficiency of carbon and hydrogen below the theoretical quantity.

		Carbon.	Hydrogen.
Tri-nitro, . .	Cellulose.	24·2	2·3
Tetra-nitro, . .		21·0	1·7
Penta-nitro, . .		18·6	1·3

But some specimens of Lenk's cotton do not even yield traces of decomposition. A parcel of Hirtenberg cotton was laid for six weeks in a pond, and not subsequently treated with potash. It was then deposited in a running stream, afterwards exposed for one month to the air; being subjected to all the various influences of dew, rain, and sun, day and night continuously. It retains all its original explosive qualities, and fails to redden litmus paper, even though the latter be wrapped in a mass of this cotton and allowed to remain for many days. The results of an analysis of this cotton were almost identical with

the calculated elements of tri-nitro cellulose, as the following table makes apparent:—

	Calculated.	Found.
Carbon, . . .	24·2	24·4
Hydrogen, . . .	2·3	2·8

The redness of litmus paper that sometimes occurs may also result from traces of organic acids, formic and acetic acids for example, both which may emanate from the turpentine of the pine chests in which the gun cotton is stored.

These acid traces should the less evoke surprise, when we bear in mind that the gun cotton in process of manufacture had been exposed for forty-eight hours to a strong acid bath; moreover, if the subject of comparison, viz: gunpowder, be tested with equal severity, similar evidence of chemical action would be forthcoming. The courses of testing must, however, be different.

Spontaneous Decomposition of Gunpowder.—Gunpowder contains sulphur as is well known. Sulphur being an element cannot be decomposed; nevertheless, it is affected by the atmosphere, though slowly. The change here is oxidation, the product being sulphurous acid. This oxidation imperceptibly affects solid cakes or bars of sulphur, but more rapidly if the sulphur be powdered. Now gunpowder contains sulphur in the highest degree of comminution, and if gunpowder be smelt, sulphurous acid is easily perceived. Other evidence is, however, available.

The sulphurous acid resulting from decomposition of sulphur is slowly changed into sulphuric acid, which latter partly attacks the saltpetre, and is partly neutralized by the potash of the ashy parts of the charcoal.

Gunpowder has a weak alkaline action, although each of the constituents of gunpowder is absolutely neutral. The alkilinity can only result from potash contained as an impurity in the charcoal. These facts borne in mind, it follows that any sulphuric acid (resulting from sulphurous acid), developed in gunpowder, should be found united with potash or sulphate of potash. Now the presence of sulphuric acid is easily demonstrable in affected gunpowder by the test of chloride of barium; and inasmuch as sulphuric acid does not exist in either of the original constituents, it must necessarily be a product of decomposition.

These observations are only intended to show that no great importance should be attached to the casual reddening of litmus paper by gun cotton. Parity of reasoning should lead to the rejection of gunpowder; and, indeed, gunpowder by long exposure to atmospheric influences is so deteriorated as to be rendered wholly unfit for ballistic uses.

Temperature at which Gun Cotton Ignites.—The rejection of gun cotton, in consequence of the changeable nature of, or the explosive quality of the material at low temperatures of the material, is so thoroughly and decidedly contradicted in the Report of Baron von Ebner, that it would be superfluous to go any further into this question; the

lowest explosive temperature of the Hirtenberg gun cotton being therein fixed at 136°; a temperature which, practically, cannot raise any doubts against the use of gun cotton.

(To be Continued.)

For the Journal of the Franklin Institute.

On the Parabolic Construction of Ships. By JOHN W. NYSTROM, C. E.

(Continued from vol. xlvi, page 396.)

It has not yet been explained how a ship is constructed by the parabolic method without calculation. Shipbuilders hesitate to study the system on account of the numerous algebraical formulas connected with it, and with the common prejudice pronounce it "theoretical." The very few shipbuilders on whom I have succeeded in impressing the importance of the parabolic method, are well convinced and have acknowledged that I employ less calculation than they have done for the same object; the formulas are numerous, because the method has revealed a great many important rules in shipbuilding, which were never before thought of, and each rule is brought to the simplest possible form.

In the practical application of the parabolic method we may proceed to construct a ship without calculation, as follows:

Having given the principal dimensions of a vessel, say 250 feet long in the water-line, beam 30 feet, and 12 feet draft of water, construct a diagram like Plate I, divided into 100 parts each way, the side B C to be a little longer than half the beam of the vessel, at whatever scale it is to be constructed. Set off half the beam from B towards C, which may be B *b*; join *b* with A. Select from Plate II, (vol. xlvi, p. 396,) a desired sharpness of the vessel, and we may adopt the figures marked 2 and 2·75 (2·75 is a sharpness between the figures 2½ and 3), which means that the exponent will be 2 for the forward and 2·75 for the aft load water-line. Draw the centre line, and set off the length of the vessel, locate the dead-flat 𝔐 according to your own judgment, and divide the fore and aft parts each into 8 equal parts, numbered as shown on Plate II. In the accompanying Table III, find the selected exponent 2 in the first column, which line contains the ordinates for the forward water-line. The fourth ordinate is 7214; find this number on the base A B, Plate I, which is at *a*, and the height *a c* is the length of the fourth ordinate for the forward water-line. The second ordinate is 3732 in the table, which will be at *d* on the diagram, and *d e* the length of the second ordinate. The remaining ordinates are found in the same way; lay them out on the plan, and draw the water-line. For the aft water-line, the ordinates in Table III are in the line of the assumed exponent 2·75. Draw the centre line for the frame drawing or body plan, set off and divide the depth, 12 feet, into 8 water-lines, as shown on Plate II, last volume; number them from the keel to the load water-line. Select on Plate II a desired shape of the dead-flat cross-section 𝔐, which may be assumed to the figure marked 4, and means that the exponent is 4. In Table II,

exponent 4, the fourth ordinate is 9375, which is at *f* on the diagram, and the line *f g* the length of the fourth ordinate. Find in the same way the remaining ordinates, lay them out on the body plan, and draw the frame; continue it above the water-line, according to your taste and the purposes of the vessel. Draw the side view of the ship, form the stem and stern as you please, project the extremities of the rail from the side view to the plan. Set off the rail-beam from the frame drawing to the plan, and locate its dead-flat as you please, say a little forward of the dead-flat of the water-line. Select the exponents for the rail, say 3·75, Table II, for the forward rail, and 2·75, Table V, for an elliptic stern. Divide the parts from the dead flat to the extremities of the rail each into 8 equal parts, and number them towards the centre; set off from B on the diagram half the rail-beam, which we may assume to be B 7; find the ordinates in the tables, and set them off from A B to A 7, as described for the water line and frame $\mathcal{M}$.

Now we are obliged to perform a calculation to find the area of half the immersed cross-section of the dead-flat frame, which is obtained by multiplying together half the beam, 15 feet, and the draft of water, 12 feet, and the product by the area co-efficient for the exponent 4, Table II, which is 0·8, or

$$\tfrac{1}{2}\ \mathcal{M} = 12 \times 15 \times 0{\cdot}8 = 144 \text{ sq. feet.}$$

Select the exponent for the displacement somewhere near that of the forward water-line, say 2·375, Table IV. The co-efficient for the fourth ordinate cross-section is ·6514, and the area

$$\mathcal{W} = 144 \times 0{\cdot}6514 = 93{\cdot}8 \text{ sq. feet.}$$

Now it is required to construct the shape of the fourth frame. The co-efficient for the fourth-line ordinate was 0·7214, which multiplied by half the beam, 15 feet, and the product by the draft, 12 feet, gives the area of the rectangle = 129·85, from which subtract 93·8 sq. feet, and the balance, 36·05, divided in 93·8, gives the exponent for the fourth frame, 2·438. Had this exponent fallen in with any one in Table II, we would have had the ordinates for the fourth frame directly from that table; but we find it to be just half-way between 2·375 and 2·5, for which we must refer to the diagram, Plate III, last volume, where we find the co-efficients for the ordinates over the exponent, 2·438, to be 4th = 812.

Set off from B on the accompanying diagrams the seven forward water-line ordinates, number and join them with A, as shown; set off from D the aft water-line ordinates, and you have a scale for all the ordinates in the sixteen frames. The fourth ordinate, 812, at *h* on A B, gives the length, *h i*. The second ordinate over the exponent 2·438, Plate II, is 275, which at *k* gives the length *k l*, and so all the frames are constructed as you see, without reference to water-lines or diagonals.

Should the shape of the frames thus formed not agree with your taste, alter them as you please, only be careful that whatever is taken in or out in one place must be taken out or in in another, so that the area will remain the same as calculated.

TABLE II.

Parabolic Construction of Ships.

Expo.	Ordinates for Frames. $b=1$.							Area.	Cent Gr	Index.
n'	1	2	3	4	5	6	7	$\frac{M}{B\times}$	$e=d\times$	i.
0·125	·0166	·0353	·0571	·0830	·1154	1591	·2289	·1111	·2647	1·256
0·25	·0328	·0693	·1109	·1591	·2179	·2929	·4054	·2000	·2777	1·468
0·375	·0488	·1023	·1616	2289	·3081	·3925	·5415	·27 7	·2849	1·641
0·5	·0646	·1340	·2094	·2929	·3876	5000	·6464	·3333	·3000	1·771
0·625	·0800	·1646	·2545	·3514	·4583	·5796	·7274	·3846	·3095	1·882
0·75	·0949	·1941	·2971	·4046	·5248	·6464	7898	4286	·3182	1·918
0·875	·1098	·2225	·3372	4589	·5761	·7027	·8379	·4666	·3261	1·981
1	·1250	·2500	·3750	·5000	·6250	·7500	·8750	·5000	·3333	2·000
1·125	·1398	·2765	·4107	·5415	·6683	·7898	·9013	·5294	·3400	1·988
1·25	·1537	·3 2 9	·4443	·5771	·7066	·8232	·9256	·5555	·3461	1·969
1·375	·1692	·3267	·4760	6145	·7404	·8514	·9386	·5789	·3518	1 929
1·5	.1815	·3505	·5059	·6465	·7763	·8750	·9558	·6000	·3571	1 897
1·625	·1950	·3734	·5341	6753	·7969	·8949	·9659	·6190	·3621	1·848
1·75	·2081	·3956	·5607	·7023	·8263	·9116	·9737	·6363	·3666	1·833
1·875	·2211	·4169	·5857	·7269	·8421	·9256	·9797	·6522	·3710	1·801
2	2375	·4376	6094	·7500	·8593	9376	·9844	·6666	·3750	1·771
2·125	2470	·4574	·6317	7707	·8756	·9474	·9879	·6800	·3788	1·745
2·25	·2595	·4766	·6527	·7897	·8899	·9558	·9907	·6923	·3823	1·716
2·375	·2716	·4950	·6725	·8071	·9026	·6628	·9928	·7040	·3857	1·692
2·5	·2838	·5129	·6912	·8232	·9139	·9687	·9944	·7142	·3888	1·667
2·625	2954	·5191	·7088	·8377	·9238	·9737	·9957	·7241	·3919	1·646
2·75	·3073	·5466	·7254	·8513	·9326	·9779	·9967	·7333	·3948	1·624
2·875	·3185	·5627	·7411	·8634	·9404	·9814	·9974	·7419	3974	1·595
3	·3301	5781	·7558	·8750	·9472	·9844	·9980	·7500	·4000	1·587
3·125	·3413	.5932	·7699	·8856	·9536	·9872	·9984	·7575	·4024	1·569
3·25	·3521	·6074	·7829	·8944	·9587	·9889	·9988	·7647	·4047	1·551
3·375	·3629	·6218	·7957	·9056	·9633	·9907	·9991	·7714	·4069	1·537
3·5	·3733	·6346	·8078	·9116	·9677	·9922	·9993	·7777	·4091	1·529
3·625	·3829	·6478	·8185	·9192	·9719	·9935	·9994	·7838	·4111	1·506
3·75	·3939	·660 0	·8284	·9256	·9747	·9944	·9995	·7894	·4130	1 492
3·875	·4040	·6722	·8383	9329	·9780	·9956	·9996	·7948	·4150	1·480
4	·4138	·6836	·8474	·9375	·9802	·9961	·9997	·8000	·4166	1·468
4·25	·4332	·7 65	·8654	·9481	·9848	9971	·9997	·8095	·4200	1·435
4·5	·4517	·7260	·8794	,9557	·9878	·9978	·9998	·8181	·4230	1·424
4·75	·4700	·7455	·8934	·9633	·9908	·9985	·9998	·8260	·4259	1·406
5	·4871	·7627	·9046	,9687	·9926	·9990	·9999	·8333	·4286	1·389
5·25	·5042	·7798	·9158	·9741	·9943	·9992	·9999	·8400	·4304	1·372
5·5	·5202	·7945	·9246	·9779	·9954	·9994	·9999	·8461	4333	1·358
5·75	5362	·8092	·9381	·9817	·9965	·9996	·9999	·8533	·4355	1·349
6	·5512	·8220	·9404	·9843	·9972	·9997	1·000	·8571	·4375	1·332
6·5	·582	·8459	·9528	·9889	·9983	·9998	1·000	·8666	·4412	1·309
7	·6073	·8665	·9627	·9928	·9989	·9998	1·000	·8750	·4444	1·289
7·5	·6336	·8845	·9713	·9945	·9994	·9999	1·000	·8823	·4473	1 275
8	6564	·8989	9767	·9960	·9996	·9999	1·000	·8888	·4500	1·256
9	·6993	·9249	·9854	·9985	·9998	·9999	1·000	·9000	·4545	1·230
10	·7369	·9437	·9909	·9990	·9999	1·000	1·000	·9090	·4583	1·208
12	·7963	·9683	·9976	·9998	1·000	1·000	1·000	·9231	·4643	1·175
16	·8819	·9991	·9999	1·000	1·000	1·000	1·000	·9412	.4720	1·133

TABLE III.

Parabolic Construction of Ships.

Expo. n.	Ordinates for Water-lines. $b=1$. 1	2	3	4	5	6	7	Area. $\mathfrak{A} = \mathfrak{A}_{BL}\times$	$s = \frac{r-l}{k}$.	Resist. k.
2	·1697	·3732	·5647	·7214	·8433	·9303	·9825	·6491	·0527	1·95
2·125	·1879	·3904	·5865	·7456	·8610	·9416	·9866	·6592	·0531	1·97
2·25	·1944	·4074	·6068	·7620	·8754	·9500	·9895	·6730	·0535	1·98
2·375	·1952	·4244	·6271	·7834	·8898	·9584	·9924	·6817	·0533	1·99
2·5	·1960	·4415	·6460	·7973	·9013	·9642	·9943	·6939	·0532	2·00
2·625	·2046	·4582	·6446	·8138	·9127	·9701	·9954	·7035	·0528	1·99
2·75	·2127	·4744	·6817	·8277	·9219	·9744	·9962	·7124	·0523	1·98
2·875	·2207	·4905	·6985	·8417	·9311	·9785	·9970	·7210	·0517	1·96
3	·2284	·5063	·7143	·8537	·9383	·9817	·9977	·7287	·0510	1·94
3·25	·2445	·5368	·7439	·8760	·9513	·9870	·9986	·7433	·0496	1·91
3·5	·2596	·5657	·7706	·8895	·9617	·9907	·9992	·7654	·0482	1·88
3·75	·2779	·5947	·7954	·9114	·9699	·9924	·9995	·7682	·0463	1·85
4	·2962	·6193	·8164	·9247	·9762	·9953	·9997	·7789	·0452	1·82
4·5	·3337	·6670	·8534	·9463	·9853	·9976	·9998	·7975	·0424	1·76
5	·3744	·7105	·8839	·9619	·9909	·9988	·9998	·8139	·0390	1·70
5·5	·4081	·7465	·9070	·9727	·9944	·9994	·9999	·8269	·0375	1·64
6	·4428	·7790	·9260	·9806	·9965	·9997	·9999	·8385	·0354	1·58
6·5	·4703	·8066	·9405	·9860	·9978	·9998	1·000	·8479	·0352	1·52
7	·5081	·8328	·9533	·9902	·9988	·9999	1·000	·8582	·0327	1·46
8	·5861	·8794	·9719	·9953	·9994	1·000	1·000	·8730	·0286	1·34
9	·6186	·9047	·9815	·9975	·9998	1·000	1·000	·8852	·0261	1·28
10	·6606	·9274	·9883	·9992	·9999	1·000	1·000	·8942	·0237	1·18
12	·7415	·9601	·9954	·9997	1·000	1·000	1·000	·9110	·0206	1·08
16	·8481	·9871	·9993	·9999	1·000	1·000	1·000	·9319	·0156	1·00

TABLE IV.

Displacement of Vessels.

Expo. n''.	Ordinate Cross-Sections $\mathfrak{w}$. $\mathfrak{W}=1$. 1	2	3	4	5	6	7	Displacement. $D = \mathfrak{W}_{L}\times$	$T = \mathfrak{W}_{L}\times$	Cent. Gr. $g = l\times$
2	·0545	·1914	·3713	·5625	·7384	·8909	·9698	·5333	·0152	·3125
2·125	·0610	·2092	·3991	5940	·7667	·8976	·9759	·5506	·0157	·3160
2·25	·0673	2271	·4260	·6236	·7919	·9135	·9815	·5663	·0162	·3189
2·375	·0737	·2450	·4523	·6514	·8147	·9270	·9857	·5813	·0166	·3278
2·5	·0805	·2512	·4777	·6777	·8352	·9383	·9889	·5952	·0170	·3333
2·625	·0872	·2695	·5024	·7017	·8534	·9481	·9914	·6083	·0173	·3388
2·75	·0944	·2987	·5262	·7247	·8697	·9563	·9937	·6204	·0177	·3412
2·875	·1014	·3166	·5492	·7455	·8844	·9631	·9948	·6325	·0181	·3469
3	·1090	·3342	·5713	·7667	·8972	·9691	·9960	·6429	·0184	·3500
3·25	·1239	·3689	·6129	·7999	·9191	·9779	·9976	·6629	·0189	·3571
3·5	·1394	·4027	·6512	·8310	·9365	·9845	·9986	·6806	·0194	·3636
3·75	·1551	·4356	·6862	·8567	·9500	·9888	·9990	·6968	·0199	·3697
4	·1712	·4673	·7181	·8789	·9608	·9922	·9994	·7111	·0203	·3750
4·5	·2039	·5270	·7736	·9146	·9751	·9956	·9996	·7364	·0211	·3846
5	·2373	·5817	·8183	·9384	·9853	·9980	·9998	·7575	·0216	·3929
5·5	·2706	·6312	·8548	·9563	·9908	·9988	·9998	·7755	·0221	·4000
6	·3038	·6757	·8844	·9688	·9944	·9995	·9999	·7924	·0227	·4062
6·5	·3366	·7155	·9078	·9780	·9966	·9996	·9999	·8047	·0230	·4108
7	·3688	·7508	·9268	·9845	·9978	·9997	·9999	·8170	·0233	·4166
8	·4309	·8080	·9540	·9920	·9992	·9998	1·000	·8366	·0239	·4250
9	·4890	·8554	·9710	·9970	·9996	·9998	1·000	·8521	·0244	·4318
10	·5430	·8906	·9819	·9980	·9998	·9999	1·000	·8656	·0248	·4375
12	·6341	·9375	·9934	·9996	·9999	1·000	1·000	·8861	·0253	·4464
16	·7777	·9991	·9998	·9999	1·000	1·000	1·000	·9126	·0261	·4629

TABLE V.

FOR ELLIPTIC STERN OF VESSELS.

EXPO.	ORDINATES OF ELLIPSES OF DIFFERENT ORDER.								AREA.	INDEX
n.	$\frac{1}{2}$	1	2	3	4	5	6	7	$\mathbf{a} = b\,l \times$	i.
2	·3398	·4840	·6616	·7808	·8660	·9204	·9682	·9922	·7854	1·603
2·25	·4108	·5490	·7147	·8274	·9004	·9495	·9801	·9958	·8154	1·544
2·5	·4670	·6042	·7657	·8627	·9252	·9546	·9873	·9978	·8382	1·495
2·75	·5174	·6514	·8029	·8901	·9434	·9749	·9932	·9989	·8564	1·453
3	·5604	·6911	·8331	·9019	·9565	·9821	·9948	·9994	·8709	1·418
3·25	·5991	·7252	·8578	·9275	·9664	·9871	·9973	·9996	·8833	1·388
3·5	·6333	·7548	·8782	·9406	·9740	·9907	·9978	·9998	·8935	1·362
4	·6096	·8021	·9003	·9595	·9840	·9950	·9995	·9999	·9075	1·318
ARC. α 30°	·0149	·0582	·1321	·2374	·3740	·5449	·7531	Sheer of Vessels.		
ARC. α 45°	·0157	·0539	·1221	·2152	·3517	·5227	·7313			
ARC. α 60°	·0160	·0474	·1086	·1972	·3190	·4794	·6946			

When the form of the vessel is thus constructed, divide the frames as required in building it, and finish the drawing accordingly.

It is not considered necessary to describe how to continue the frames to the rail, which the ship's constructor can do in the ordinary way. The sheer is set off from B to S, and the ordinates taken from Table V.

The displacement of the vessel will be

$$T = 288 \times 250 \times 0{\cdot}0166 = 1195{\cdot}2 \text{ tons.}$$

The co-efficient 0·0166 is found in Table IV, for the exponent of the displacement 2·375.

The last column, i, Tables II and V, contains the index for the length u of a parabola or ellipse.

$$u = \sqrt[i]{b^i + l^i}.$$

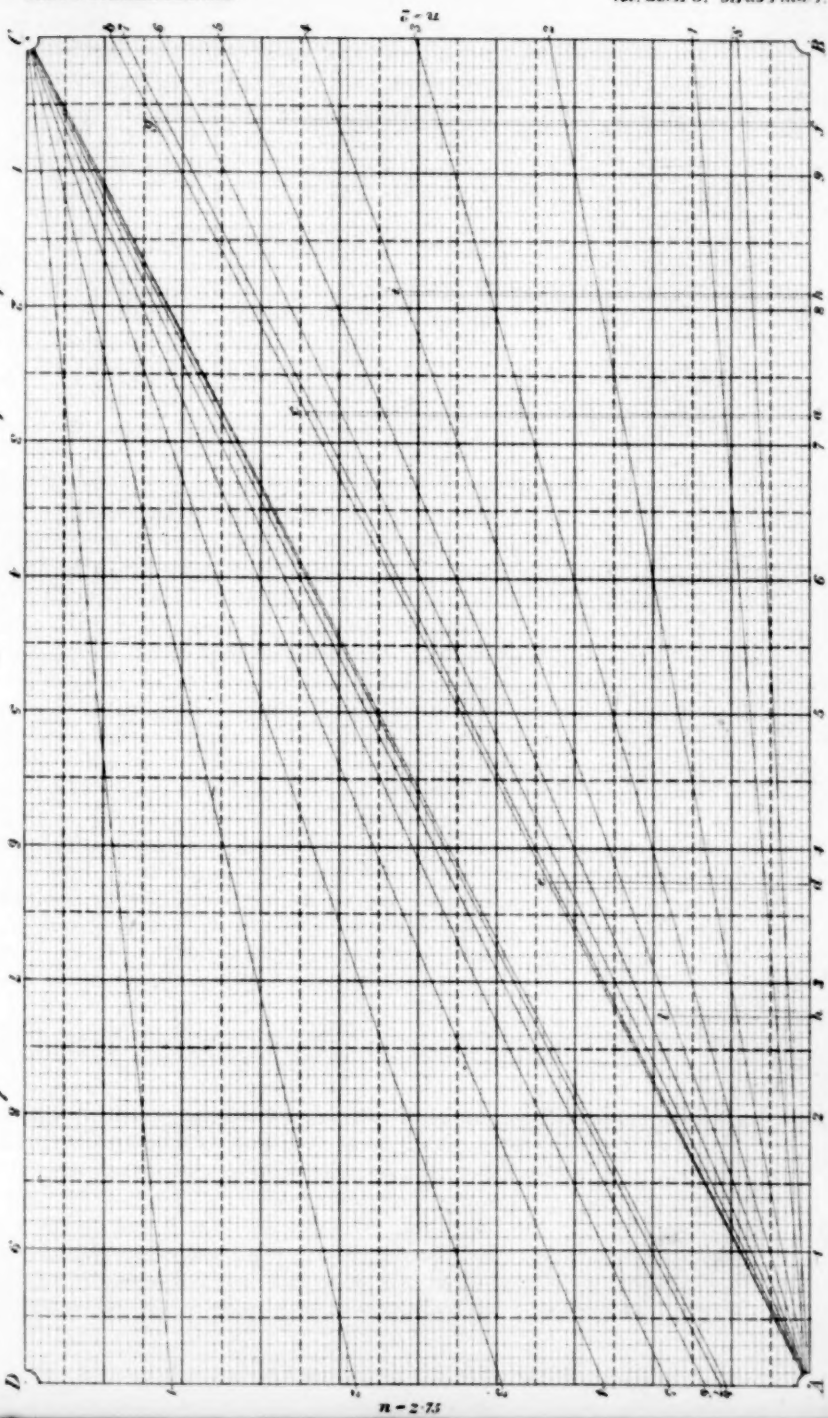
The corners on the diagrams are rounded in, to guard the ordinate lines from the centres.

When the shipbuilder becomes accustomed to select the exponents, he can set his constructor or draftsman at work to construct just exactly what he wants, without his immediate attention.

The Pneumatic Despatch.

From the London Builder, No. 1069.

The report to be presented to the third ordinary general meeting of the company, having referred to the removal of the experimental tube and machinery from Battersea, and its having been laid underground from the Euston Station of the London and North-Western Company to the district post-office in Eversholt Street, a length of 600 yards, states that on the 20th February last, the Post-office authorities discontinued their street conveyances, and entrusted the company with the transmission of the mails, and that the service of the district had



Systems of Double Construction of S. Ships

TABLE V.

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2	·3398	·4840	·6616	·7808	·8660	·9204	·9682	·9922	·7854	1·603
2·25	·4108	·5490	·7147	·8274	·9004	·9495	·9801	·9958	·8154	1·544
2·5	·4670	·6042	·7657	·8627	·9252	·9546	·9873	·9978	·8382	1·495
2·75	·5174	·6514	·8029	·8901	·9434	·9749	·9932	·9989	·8564	1·453
3	·5604	·6911	·8331	·9019	·9565	·9821	·9948	·9994	·8709	1·418
3·25	·5991	·7252	·8578	·9275	·9664	·9871	·9973	·9996	·8833	1·388
3·5	·6333	·7548	·8782	·9406	·9740	·9907	·9978	·9998	·8935	1·362
4	·6096	·8021	·9003	·9595	·9840	·9950	·9995	·9999	·9075	1·318
ARC. 30°	·0149	·0582	·1321	·2374	·3740	·5449	·7531			
ARC. 45°	·0157	·0539	·1221	·2152	·3517	·5227	·7313		SHEER OF VESSELS.	
ARC. 60°	·0160	·0474	·1086	·1972	·3190	·4794	·6946			

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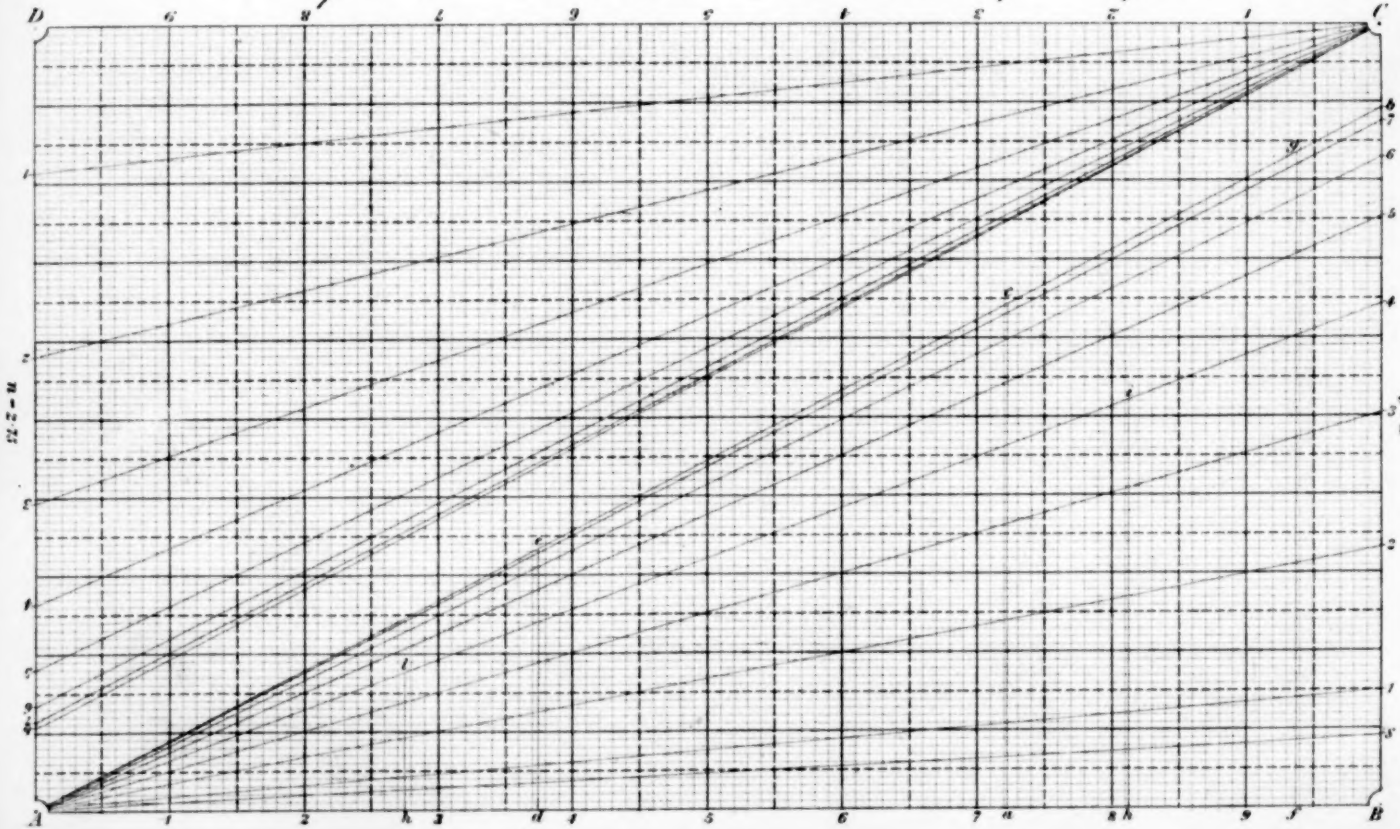
Systrom's Parabolic Construction of Ships



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T. Sinclair's lith. Philadelphia.

since been entirely performed by the company. Thirty trains per diem (Sundays excepted) have been despatched with perfect regularity, and upwards of 4000 trains have run without impediment or delay. The time occupied in the transmission has not exceeded 70 seconds. The daily cost of working has averaged £1 4s. 5d.; and five times the number of trains could have been conveyed without any appreciable increase of expense.

DECISIONS IN PATENT CASES.

Reported by H. Howson, Esq., Philadelphia.

Decision of the Examiner.

In the matter of the Interference between the application of B. H. Lightfoot for mode of Treating Tanned Leather, and the application of A. H. Eastman for a similar invention. C. F. Stansbury, Esq., Counsel for A. H. Eastman; H. Howson, Esq., Counsel for B. H. Lightfoot.

U. S. Patent Office, July 27, 1863.

To the Commissioner of Patents:

Sir:—I have the honor to submit herewith my report and decision in the matter of interference between the application of Benjaman H. Lightfoot, for mode of treating tanned leather, and the application of Alexander H. Eastman for a similar invention.

The invention in this case consists in producing a new composition to be used in that treatment of leather technically called "dubbing," the novelty consisting in substituting the oily matters derived from Petroleum for the animal oils commonly used for that purpose; there is some difference between the inventions as described and claimed by the two inventors, but the difference does not appear to be of much importance. The samples of leather produced are all of very nearly the same character. Eastman claims the application of the residuum of Petroleum treated as herein described, to the finishing of leather as a substitute for the oils now used for that purpose, all as set forth in this specification; he obtains his oils by treating the residuum left in the still. After the distillation of Petroleum, the oil so prepared is combined with tallow, and used for dubbing.

Lightfoot claims "the treatment of tanned leather by the application to the same, substantially in the manner described, of Petroleum or any oily hydrocarbons, holding paraffine in solution in combination with tallow or its equivalent."

From this statement it is clear that he meant to embrace the invention described by Eastman in general terms, although he does not describe the exact mode of preparation or the same materials with which to prepare it as set forth by Eastman. Were it shown that Eastman's preparation was a better or cheaper material, there might be grounds for allowing its patentability independently of Lightfoot's invention. But the testimony of the experts shows that there is no essential difference between the compositions described by Lightfoot and that of

Eastman; besides, Lightfoot states that the heavy oil from Petroleum such as used for lubricating machinery may be used with the best effect. The inventions are therefore, as far as appears from the testimony, substantially the same, and the interference was properly declared.

A large amount of testimony was produced on each side, and the case appears to be fully and fairly presented for decision; the inventors where wholly independent of each other, and each was no doubt perfectly unaware what the other was doing. The experiments of both extended over a considerable period of time, sufficient in fact to show that neither manifested much diligence, probably from the fact that neither fully appreciated the value of the invention he was making. Both parties made the invention and reduced it to practice, so that either would have been able to obtain a valid patent had the other not applied.

Eastman made oath to this invention on the 20th, and Lightfoot on the 30th day of January, 1863.

The testimony for Eastman shows that he began to use some kind of Petroleum product for greasing leather in January or February, 1861, but the first distinct mention of the invention in dispute was in March, 1862. The witnesses Huff, Blanchard, and Horton, prove that Eastman had at that time made a practical use of his invention, and the invention is that claimed by Lightfoot, that is the combination of a hydrocarbon with tallow, for a leather dressing. Eastman's other witnesses, as Taylor and Horton, mention the use of some preparation from Petroleum for oiling belts, boots, &c., during the months of January, February, July, and September, 1861. This was at the oil wells in Pennsylvania, but as there is no mention of the use of tallow with the oil, or any application to undressed leather, this testimony is not material to the issue, except to show that Eastman was at that time making the preliminary experiments which led to his invention.

On behalf of Lightfoot it is shown that in September, 1860, he sent a bottle of coal oil to Bush and Clark at Wilmington, Delaware, who were engaged in tanning and currying leather, to be used in dubbing leather. But no application was made of this oil to leather until 1863. William Lightfoot says, that in the latter part of April, or 1st of May, 1861, B. H. Lightfoot showed him a piece of leather that had been curried or dressed with coal oil, and also a sample of oil marked "N." The witness, Chas. Toppan, says that between the 22d and 26th of March, 1861, he was in the office of Lightfoot in Philadelphia, when the latter showed him some new leather and some oil, the oil to be used instead of "Straits" or "Bank oil," in the stuffing of leather; Toppan remembered what was told him by Lightfoot, and in the latter part of the summer of 1861, called the attention of curriers to the use of coal oil for stuffing, and sold for that purpose a considerable quantity of oil.

It appears that during the months of March, April, and May, 1861, Lightfoot had a very distinct idea of his invention, and made experiments sufficient to test its efficacy. Why the matter was not followed up more closely does not appear. But for the aid of Toppan there is

no probability that the invention would have been tested on a large scale. It was however so tested by the persons to whom Toppan suggested the use of Petroleum products as substitutes for Straits or Bank oil.

The sum of the testimony for Lightfoot is, that in September, 1860, he sent a sample of coal oil to a currier to be tested. But no test was made, and the currier did not believe it would answer the purpose intended. In March, 1861, he applied the oil to a sample of new leather, and showed it to Toppan, and at the same time explained the invention to Toppan. In April or May, 1861, Lightfoot showed a sample of oil and a specimen of leather which had been dressed with the oil to his brother; from this time it does not appear that Lightfoot did anything until he made his application for a patent in January, 1863.

The sum of the testimony for Eastman is, that in the early part of 1861, he used thick oil for greasing belts, boots, &c., that is, for softening leather. In March, 1862, he applied a stuffing of tallow and heavy oil to a quantity of new leather; in July, 1862, he had some other sides of leather dressed with the same material. The experiments seemed to have been satisfactory; no reason is assigned for the delay in applying for a patent.

There is no doubt that Eastman made and applied the invention as early as March, 1862. There is no doubt that Lightfoot conceived the invention as early as September, 1860, but did not apply it on a working scale till quite recently. But his communication of the invention to Toppan in March, 1861, was such as to enable him to impart the invention to others skilled in the art, and it was so imparted, and it was used by curriers many months before either party made application for a patent.

Although Eastman's patent had been ordered to issue before Lightfoot's application was filed, the interval between the filing of the two applications was only nine days.

After a careful examination of the testimony produced, I am of the opinion that Lightfoot first made the invention in dispute, and I decide the question of priority of invention in his favor, and recommend that a patent be granted to him for his claim as it now stands.

Could it be shown on the part of Eastman that the particular composition claimed by him possesses properties which make it superior to the preparations made from the ordinary heavy oils as described by Lightfoot, a subordinate patent might be allowed to him for his composition as described and claimed; unless such superiority can be shown, I recommend that Eastman's application be rejected.

B. S. Hedrick, *Examiner.*

Decision of the Board of Examiners in Chief.

U. S. Patent Office, 12th October, 1863.

Interference between the application of Benjamin H. Lightfoot for a Patent for Dressing Leather, and the application of Alexander H. Eastman for a like patent.

On appeal to the Examiners in Chief, Eastman endeavors to secure

to himself the monopoly of "the application of the residuum of Petroleum, treated as described in his specification" to the finishing of leather as a substitute "for the oils previously employed for that purpose. His specification seems to require as a prerequisite to the proposed use of Petroleum, that it should be treated with certain acids and alkalis, in a way which he describes."

Lightfoot's specification claims exclusively "the treatment of tanned leather by the application to the same, substantially in the manner described of Petroleum, or any oily hydrocarbon, holding paraffine in solution, in combination with tallow or its equivalent." As Eastman contemplates mixing his oil with tallow, after it is prepared according to his instructions, before applying it to the hides, the propriety of declaring the interference is manifest. It is true that Eastman uses no oil but such as has been treated according to this method, and Lightfoot uses Petroleum in all its forms.

But if Eastman was the first to discover his method, Lightfoot's patent if he can have one at all, should be made subordinate upon the face of it to that of Eastman. And the same remark may be made respecting Eastman's, should Lightfoot be considered the earliest in the race of discovery. Lightfoot shows that he had conceived the idea of substituting Petroleum, or some of its products, for the oils used in curing leather, as early as in September, 1860. At that date he actually described the process to others, and made an application of some of the oil to harness. This cannot, however, be regarded as reducing his theory to practice, nor even as demonstrating its practicability. It merely showed that the oil would soften leather, which had become hard after having been tanned.

But this must have been well known to the operatives at the oil wells, from the time when they were first worked. In order to show how hides in the process of tanning would be affected, it was necessary to first stiffen the oil with tallow, or something equivalent, so that the mixture would adhere to the skins when hung up, and then to apply it to hides, which had been partially tanned. Whatever Lightfoot may have been doing meanwhile, there is no evidence of his having made any further progress in his discovery until March, 1861. He then exhibited a piece of leather to a dealer in oils, Charles Toppan, and at the same time informed him that it was dressed with Petroleum oil.

The last of April or 1st of May after, he showed a piece to his brother William Lightfoot, and made the same remark about it. Mr. Toppan testifies further that the sample exhibited to him, corresponded precisely to other leather, which he produced upon his examination, and knew to have been dressed with Petroleum oil. At that time Lightfoot appears to have been entirely ignorant that any one else was prosecuting the same course of inquiry, and manifested no eagerness to establish his priority. His remarks, taken in connexion with his exhibition of the sample of his work, may fairly be considered as a part of the *res gestæ*. And the evidence of the two witnesses proves satisfactorily that in March 1861, Lightfoot had matured his discovery,

had shown its feasbility, and had reduced it to actual practice. Nothing was wanting to render the invention complete on his part.

Eastman is a tanner and currier by trade, but had become interested in the oil wells in Pennsylvania in January, 1861, and was engaged in carrying one of them on. His mind seems to have been at once struck with the idea that the oil might be substituted for that which he had been accustomed to use in stuffing leather. He imparted the idea directly to several of his associates, and in order to demonstrate its correctness, made various applications of it to leather which had been previously dressed. For the reasons given above, these experiments cannot be regarded as having reduced his theory to any practical form. Before experimenting directly upon hides, or anything but leather already tanned, and before preparing the oil with tallow or the like, he seems to have supposed that the oil must first be subjected to some purifying process, and to have addressed himself entirely to perfecting such a process. At any rate, there is no evidence that he ever made any application of the oil to hides in the process of tanning before March, 1862, when two tanners, Huff and Blanchard, at his instance, used the oil in lieu of the fish oil ordinarily employed in tanning some skins. Upon the principles heretofore laid down, this is the earliest date at which he can be said to have so far matured his invention as to have entitled himself to a patent; and it clearly places him far behind Lightfoot.

As Lightfoot's counsel places much reliance upon Toppan's having induced the tanners with whom he dealt, to use this oil for stuffing hides, and upon his having sold them large quantities for the purpose, it is proper to remark that Toppan does not carry this back any further than nine months previous to his testifying which was in March, 1863. It is evident that nothing of the kind had been done by him previously to July, 1862, when we wrote to Lightfoot on the subject, but failed to elicit any reply.

It is objected to Lightfoot's application that by his long delay in presenting it he has lost his right. This delay does not amount to two years. Besides that, his failure in business and straightened circumstances constitute in the opinion of this Board, a fair answer to the objection. That he paid debts to a large amount, if it were more clearly shown, does not weaken his claims, but rather entitled him to favorable consideration. It was honorable in him to appropriate his scanty means to such a purpose, before embarking in an undertaking which must have been considered hazardous.

The decision of the primary Examiner, adjudging Lightfoot to be the prior inventor, and rejecting Eastman's application, is therefore affirmed.

J. H. Hodges,
J. J. Coombs,
Examiners in Chief.

Mr. Eastman after this decision withdrew his claims, and the patent dated November 17, 1863, was granted to B. H. Lightfoot.

For the Journal of the Franklin Institute.

Investigation of Formulæ for Determining the proper size of Shafts and Piston Rods. By D. M. GREENE, 2d Assistant Engineer, U.S.N.

An article published in a recent number of the *Journal* contains several useful formulæ for determining the proper sizes of various important parts of the steam engine; but as these formulæ are not accompanied by any investigations or explanation of the processes by which they were obtained, they fail to meet the requirements of the intelligent and careful designer of steam machinery.

It is the purpose of the present paper to develop formulæ for calculating the diameters of *Shafts* and *Piston Rods*,—divesting the investigations of such technicalities as would tend to embarrass the general reader.

SHAFTS.—*Wrought Iron.*—*The moment of a pressure tending to produce rotation about an axis, or to resist such motion, is equal to the intensity of the pressure or resistance multiplied by the lever arm with which such pressure or resistance acts.*

In order to determine the relation between the diameters of shafts and their moments of resistance to torsional strain,

Let s = torsional strength per square inch of transverse sectional area of shaft.

a, a_1, a_2, &c., = the sectional areas.
d, nd, $n_1 d$ = their diameters.
r, nr, $n_1 r$, &c., = their lever arms of resistance.
m, m_1, m_2, &c., = their moments.

Then,

$$m = a\,s\,r \qquad m_1 = a_1\,s\,nr$$

whence
$$m : m_1 :: a\,r : a_1\,nr. \quad . \quad . \quad (1)$$

But, $a = \cdot 7854 d^2$ $\quad a_1 = \cdot 7854 n^2 d^2$

Substituting these values in (1) we get

$$m : m_1 :: \cdot 7854 d^2 r : \cdot 7854\, n^2 d^2 nr :: 1 : n^3. \quad (2)$$

Similarly,

$$m : m_2 :: 1 : n_1^3 \quad . \quad . \quad (3)$$

From (2) and (3) we get

$$m_1 : m_2 :: n^3 : n_1^3 \quad . \quad . \quad (4)$$

Hence, the moments of resistance of shafts to torsional strain vary directly as the cubes of their diameters.

If d = one inch in the preceding notation, 1, n, n_1, n_2, &c., will represent the number of inches in the diameters of the shafts.

If, again, $n = 1$, (4) becomes

$$m_1 : m_2 :: 1 : n_1^3;$$

whence
$$m_2 = m_1 n_1^3; \quad . \quad . \quad (5)$$

Or *the moment of resistance to torsion of a shaft whose diameter is n_1 inches, is equal to the moment of resistance of a shaft whose diameter is one inch multiplied by n_1^3.*

If now the value of m, for a shaft one inch in diameter be deter-

mined experimentally, the moment of resistance of any other shaft is readily determined.

The following is the result of an experiment made for the purpose of determining the value of m_1.

"*A square bar of wrought iron (Ulster Iron Co.'s,) with a journal one inch in diameter and one-fourth inch in length, twisted with* 326 *pounds and broke with* 570 *pounds applied at the end of a lever* $2\frac{1}{2}$ *feet in length.*"

Now a weight of 570 lbs. acting with a lever arm of $2\frac{1}{2}$ feet is equivalent to $570 \times 2\frac{1}{2} = 1425$ pounds acting with an arm of 1 foot = 1425 lbs. ft.

The value just obtained would be the value of m_1, if we use the ultimate strength of the iron; but in practice, to insure safety, it is customary to use only about *one-sixth*, which would give $\frac{1425}{6} = 237{\cdot}5$ for m_1; since, however, the iron used in the experiment above was of a superior quality and strength, we shall take

$$m_1 = 200 \quad . \quad . \quad . \quad (6)$$

Resuming the use of d for the diameter of any shaft in inches; and putting for m_1 the value just found, eq. (5) becomes

$$m = 200 d^3; \quad . \quad . \quad . \quad (7)$$

m being the moment of safe resistance in pounds feet of the shaft whose diameter is d.

If P = the pressure on the crank pin,
and a = the length of the crank arm,

then will,

$$m^1 = \text{P}\, a, \quad . \quad . \quad . \quad (8)$$

be the moment of pressure, which must be equal to the moment of resistance of the shaft; or, (7) and (8) (taking the direction of P parallel to the piston rod),

$$200 d^3 = \text{P}\, a \quad . \quad . \quad . \quad (9)$$

Now, to find the value of P in terms of the dimensions of the cylinder and the pressure upon the piston,

Let D = the diameter of the cylinder in inches.

s = the stroke in feet $= 2a$

p = effective pressure in lbs. per square inch on the piston (maximum).

= the boiler pressure per steam gauge + vacuum.

Then will

$$\text{P} = {\cdot}7854 \text{D}^2 p, \qquad a = \frac{s}{2},$$

and $\text{P}\, a = \frac{{\cdot}7854}{2} \text{D}^2 ps$; which in (9), gives

$$200 d^3 = \frac{{\cdot}7854}{2} \text{D}^2 ps,$$

whence,

$$d^3 = \frac{{\cdot}7854}{400} \text{D}^2 ps$$
$$= {\cdot}002 \text{D}^2 ps.$$

$$\therefore\ d = \sqrt[3]{\cdot 002 D^2 ps}. \qquad . \qquad . \qquad (10)$$

for the shaft of a single engine.

For a double engine, with the cranks placed at right angles, we have as before

$$200 d^3 = P^1 a^1, \qquad . \qquad . \qquad . \qquad (11)$$

in which P^1 represents the pressure upon the two crank pins, and a^1 the lever arms with which they act, when the strain upon the shaft is a maximum; which will be when each crank makes an angle of 45° with the direction of the piston rod.

In this position we shall have,

$$a^1 = a \cos. 45°$$
$$= \frac{s}{2} \times \cdot 7$$

and since there are two cylinders, we shall have, $P^1 = 2 \times \cdot 7854 D^2 p$;

$$\text{and } P^1 a^1 = \frac{2 \times \cdot 7 \times \cdot 7854\ D^2 ps.}{2}$$

This value substituted in (11) gives

$$200 d^3 = 2 \times \cdot 7 \times \cdot 7854\ D^2 ps.$$

whence,

$$d^3 = \frac{2 \times \cdot 7 \times \cdot 7854}{400} D^2 ps.$$
$$= \cdot 0027\ D^2 ps.$$

and $$\sqrt[3]{\cdot 0027\ D^2 ps}. \qquad . \qquad . \qquad (12)$$

For an engine with three cylinders, having its cranks placed at angles of 120°, we shall have the maximum torsional strain on the shaft, when one crank is perpendicular to, and the two others each make an angle of 30° with the direction of, the piston rod.

In this case we shall have

$$200 d^3 = P a + P a \text{ sin. } 30° + P a \text{ sin. } 30°$$
$$= \frac{P s (1 + 2 \text{ sin. } 30°)}{2}.$$
$$= P s.$$
$$= \cdot 7854\ D^2 ps.$$

whence,

$$d^3 = \frac{\cdot 7854}{200} D^2 ps.$$
$$= \cdot 0039\ D^2 ps.$$

and $$d = \sqrt[3]{\cdot 0039\ D^2 ps}. \qquad . \qquad . \qquad . \qquad (14)$$

Comparing now (10), (12), and 14), supposing D, p, and s constant, we get

$$d_1 : d_2 ; d_3 : : \sqrt[3]{20} : \sqrt[3]{27} : \sqrt[3]{39}$$
$$: : 1 : 1{\cdot}1 : 1{\cdot}25;$$

whence it appears that diameters of the shafts of single, double, and

treble engines, having cylinders of the same size and using the same pressure of steam, are to each other respectively as 1, 1·1 and 1·25.

Recapitulation.

For Single Engine (10).

$$d = \sqrt{\cdot 002 D^2 ps}.$$

For Double Engine (12).

$$d = \sqrt{\cdot 0027 D^2 ps}.$$

For Treble Engines (14).

$$d = \sqrt{\cdot 0039 D^2 ps}.$$

PISTON RODS.—(*Wrought Iron*).—For all the knowledge we possess in relation to the resistance of columns to crushing strains we are directly indebted to experiment.

It is found that columns of wrought iron will bear without crushing, per square inch:—

When their lengths are less than 12 diameters,		14,225 lbs.
" " " " between 12 and 24	"	11,877 "
" " " " greater than 24	"	7,112 "

In practice we may take one half these values.

Let s = the safe resistance of the material per square inch.
d = diameter of the piston rod in inches.
a = area of transverse section in square inches.

Then we shall have for the pressure which any rod will bear with safety

$$P = a\,s$$
$$= \cdot 7854 d^2 s.$$

Substituting now in this expression, for s, the safe resistances indicated above, we get,

$$P = \frac{14225}{2} \times \cdot 7854 d^2 \quad . \quad . \quad (1)$$

$$P_1 = \frac{11877}{2} \times \cdot 7854 d^2 \quad . \quad . \quad (2)$$

$$P_2 = \frac{7112}{2} \times \cdot 7854 d^2 \quad . \quad . \quad (3)$$

These expressions must be made equal to the pressure upon the pistons. To obtain an expression for the effective pressure upon any piston:—

Let D = diameter of cylinder in inches.
p = effective pressure per square inch upon the piston = pressure per steam gauge vacuum.

Then we shall have for the whole pressure on the piston:—

$$P = \cdot 7854 D^2 p.$$

Equating successively the values in (1), (2), and (3) with the preceding, we get

1°. $$\frac{14225}{2} \times \cdot 7854 d^2 = 7854\, D^2 p.$$

whence $$d^2 = \frac{2 \times \cdot 7854}{14225} D^2 p$$

and $$d^2 = 0 \cdot 11 D \sqrt{p} \quad . \quad . \quad . \quad (4)$$

2. $$\frac{11877}{2} \times \cdot 7854 d^2 = \cdot 7854 D^2 p.$$

whence $$d^2 = \frac{2 \times \cdot 7854}{11877} D^2 p$$

and $$d = \cdot 013 D \sqrt{p}. \quad . \quad . \quad (5)$$

3. $$\frac{7112}{2} \times .7854 d^2 = \cdot 7854 D^2 p$$

whence $$d^2 = \frac{2 \times \cdot 7854}{7112} \times D^2 p.$$

and $$d = \cdot 017 D \sqrt{p} \quad (6)$$

Steel Rods.—The relative abilities of wrought iron and steel to resist crushing strains are as 1745 to 2518; hence, the transverse sectional areas of piston rods made of these materials, should be inversely proportional to these numbers; or their diameters should be inversely proportional to the square root of of 1745 and 2518.

Now, $$\sqrt{\frac{1745}{2518}} = \cdot 83$$

and (4) becomes $$d = \cdot 83 \times \cdot 011 D \sqrt{p}$$

$$= \cdot 009 D \sqrt{p} \quad . \quad . \quad (4)^a$$

Similarly, (5) becomes $$d = \cdot 83 \times \cdot 013 D \sqrt{p}$$

$$= \cdot 011 D \sqrt{p} \quad . \quad . \quad (5)^a$$

and (6) becomes $$d = \cdot 83 \times \cdot 017 D \sqrt{p}$$

$$= \cdot 014 D \sqrt{p} \quad . \quad . \quad (6)^a$$

Recapitulation.

When

	Wrought Iron.	Steel.
$l < 12d$,	$d = \cdot 011 D \sqrt{p}$	$d = \cdot 009 D \sqrt{p}$
$l > 12d$ and $l < 24d$	$d = \cdot 013 D \sqrt{p}$	$d = \cdot 011 D \sqrt{p}$
$l > 24d$	$d = \cdot 017 d \sqrt{p}$	$d = \cdot 014 D \sqrt{p}$

l being the length of the rod.

If different values be assigned to p in the above formulæ, tables may be readily constructed. The three cases taken, correspond to *short*, *medium*, and *long* strokes. Hence the formula for d when $l < 12d$ would apply to the piston rods of propeller engines; but since the speed of piston in the propeller engine is considerable, it would perhaps be better to use the formula (5) or $(5)^a$, in determining the diameters of their rods; in any other case, a mental comparison between the length and diameter of the cylinder will show which formula should be used.

Naval Academy, Newport, R. I., Dec. 9, 1863.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, December 17, 1863.

John C. Cresson, President, in the chair.

John Agnew, Vice President.

Robert Briggs, Recording Secretary, *pro tem.*

The minutes of the last meeting were read and approved.

A letter was read from the Royal Society, London.

Donations to the Library were received from the Royal Society, and the Society of Arts, London; la Société Industrielle de Mulhouse, France; the Oesterreichischen Ingenieur-Vereines, Vienna, Austria; the Commissioner of Agriculture, Washington, D. C.; Prof. John F. Frazer, Frederick Graff, Esq., and John Warner, Esq., Philadelphia.

A donation to the Cabinet of Models, from Rufus A. Wilder, Esq., Schuylkill Haven, Pennsylvania.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of November was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (12) were proposed, and those proposed at the last meeting (24) were duly elected.

Nominations were made for Officers, Managers, and Auditors of the Institute for the ensuing year.

Prof. Fleury submitted specimens of the incombustible papier-mache moulds used by Prof. Vander Wayde in his process of stereotyping.

Mr. John W. Nystrom said:—Since the last meeting I have made some inquiries about paper moulds for stereotyping, and as far as I am able to trace it back, it appears to be an old American invention, experimented upon and brought to some perfection by the late Mr. L. Johnson, of this city, some thirty years ago; the process has since been sold to Mexico. It has been gradually improved, and lately brought to greater perfection. About five years ago an Italian in this country made a great improvement in the art, by inventing an incombustible solution for the paper mould, consisting of a strong glue mixed with alum and plaster of paris, and the process is now in successful operation in different parts of the world. It is recommended by R. Hoe & Co., and now employed on twelve of their printing presses, of which the Philadelphia Inquirer is one, and the only one in this city. The New York Herald, Tribune, and Times are printed from plates cast in paper moulds; three papers in London, one in Manchester, and one in Paris. Paper moulds are also employed for book printing in Manchester. I have brought to the meeting one stereotype plate and paper moulds from which to-day's Inquirer was produced, and contribute the same to the Cabinet of the Institute. The plate, as you see, is cylindrical-convex on the face, made to fit the cylinder press,

which latter makes 20,000 impressions per hour. It requires only sixteen minutes to mould, cast, and finish the stereotype plate. I have here also samples of plates from the Smithsonian Institution, which may be of interest to printers. This plate is cast from a mould made of two parts of China clay and one part of powdered soapstone, mixed with water to a tough dough, spread out very thin on an iron plate, and the type form is pressed into it. The other plate is made of clay, instead of type metal; the Catalogues of the Smithsonian Institution are printed from such plates, made up of small pieces, one for each book, which can at any time be arranged in any desired order; such plates are very cheap, but do not admit of alterations. I have here also a sample of an electrotype plate from my Pocket Book.

Mr. Fleury then read the following paper:

Carbonic Acid, Chlorine, Fluorine, Hydrogen, Sulphurous, and Sulphuretted Hydrogen Gases have already taken a prominent place in our industrial pursuits, and it gives me much pleasure to be able to present to you this evening a new device for producing these gases, by a very simple and cheap apparatus, the invention of one of our members, Mr. Frederick M. Ruschhaupt, of Berlin, Prussia.

I now exhibit to you two modifications of this apparatus, one of a very simple construction, which conveys the gas by its own pressure to the place where it is required; the other, an arrangement for a continuous equal pressure, and which can at all times be obtained, an advantage that no other apparatus possesses. These machines can be made, the one constructed to convey gas by its own pressure at $75—the one which gives a continuous equal pressure at $150—while the machines now in use cost at least $300. These apparata are made of wood and lead (or other suitable materials), and are sufficiently strong for all practical purposes. Their construction is such that the evolution of the gas can be stopped at any moment, and the apparatus can be cleaned without incurring any danger.

The arrangement whereby any desired pressure can be obtained and kept up is a very valuable one. For the numerous applications of such gases as carbonic acid, where it is sometimes very important to keep up the same pressure, this machine is admirably adapted. For the manufacture of soda and other mineral waters, for the new system of baking aërated bread, for the laboratory, as well as for the hospital and private physician, these machines can be well recommended.

By some modification, other gases, such as chlorine and sulphuretted hydrogen, can be evolved cheaply and effectually. The machine suggests other applications, as for instance, the preparation of hydrogen and carburetted hydrogen gases, *ad libitum*, for the production of light and heat. The preparation of hydrofluoric acid for etching on glass, or for dissolving of silica, may also be safely, easily, and cheaply effected by these same machines.

Those who desire further information may address Mr. G. F. Kershaw, Attorney, No. 324 Chestnut Street, in whose hands the American patent and all papers relating to the subject have been placed by the inventor.

Prof. Fleury read the explanation of the advantages of Dr. Vander Weyde's patent apparatus for the making and administering of Nitrous Oxid Gas, for anæsthetic purposes.

The administration of nitrous oxid, or so-called laughing gas, during short but painful operations, cannot be enough recommended; in using it, we avoid entirely the shock produced on the system by intense pain, a shock especially injurious to persons of a delicate nervous temperament.

This gas being itself a supporter of combustion and of life, does not produce any unpleasant effects when administered properly, much less has it ever proved fatal; a fact which by no means can be stated about chloroform, which far from supporting life extinguishes it, when used in large doses, as has been proved by numerous fatal results, consequent to its administration.

It is a singular fact that among the three anæsthetics now in use, ether, chloroform, and nitrous oxid, the first is combustible itself, the vapor being just the opposite of a supporter of combustion and life; the last, nitrous oxid, is a powerful supporter of combustion and of life, and chloroform is neither combustible nor a supporter of combustion.

Ether therefore is worse than chloroform; its vapor is directly suffocating, and its effect is due to neither more nor less than a partial suffocation, which very easily may be carried too far, and often has been carried too far; this accounts for its unpleasant after effects, even when administered in a moderate dose.

Professor Vander Weyde has come to this conviction not only by the study of the chemical properties of ether, but by the observation of its physiological effects, made during several years in the New York hospitals and medical colleges; for this reason he is of opinion that only two anæsthetics should be used, namely, nitrous oxid and chloroform.

The first acting very rapidly and its effects lasting only a short period of time, is appropriate for all surgical operations of little duration, like most of those required in dentistry; the latter (chloroform) acting slower and its effects being more lasting, is only suitable when a prolonged effect is desired, as in capital amputations, and, in general, all protracted surgical operations.

All anæsthetics act on the system similar to alcohol, the smallest effective dose produces exhilaration, a little more great excitement, which in different individuals manifests itself in a great variety of ways, a greater dose produces sleepiness, and the maximum dose perfect insensibility (total drunkenness). The difference between nitrous oxid and the other anæsthetics is, that the first being a supporter of combustion and respiration, stimulates the nervous system, and produces an increase of vitality, the others being non-supporters of combustion and respiration, depress the nervous system and bring vitality below the standard, both with the same final result, *perfect unconsciousness;* the difference only is that the unconsciousness produced by the increase of vital action is harmless, and the same result produced by the depression of vital action is injurious, and may prove

fatal; in other words, that the excitement or unconsciousness following the use of nitrous oxid is harmless in its results, and the excitement or unconsciousness following the use of ether or chloroform is connected with danger.

It is a fact stated by Dr. Colton, who has administered the nitrous oxid to about 20,000 persons, more individuals than any other man living, that never any fatal result has followed; in the meantime, it is estimated that upwards of 3000 lives have been lost during the administration of ether and chloroform.

Since the nitrous oxid has been introduced for the above-mentioned purposes, it has been observed that in some instances persons after having used it, felt nausea and even vomited; now this is by no means the fault of the gas, but of the method of administering it.

Thus far it has in fact always been administered in a most disgusting manner; an india-rubber bag or bladder, of four, six, or eight gallons contents, provided with a stop-cock and mouth-piece, is filled with the gas and placed to the mouth of the patient, who has to breathe out and in the bag: as now during respiration the lungs give continually off carbonic acid, which is thrown out of the system by the act of expiration, as an injurious poisonous substance; this expired carbonic acid goes in the bag, mingles with the gas, dilutes it and makes it impure; more than that, it poisons it; all breathing in and out of a bag causes us to breathe our own breath over again, which is nothing less than breathing a poisoned atmosphere, rendered continually more so by every expiration; any one may verify this by breathing out and in such a bag, when simply filled with atmospheric air, after a very few minutes giddiness and nausea are the result, and those are the regular symptoms of poisoning by carbonic acid.

To avoid this objection, the Professor first constructed a stop-cock with valves, which opened and closed in such a way that the exhaled gas was expelled in the atmosphere and lost; he found, however, that in this way the amount required to affect some individuals was so extravagantly large, and the bags and quantities necessary so enormous, that he soon gave this up as too expensive and troublesome.

In the same time, the manner in which the gas has been produced and preserved thus far is cumbersome and imperfect in the extreme. Nitrous oxid is developed by decomposing nitrate of ammonia by heat in a glass retort, producing thus nitrous oxid and water, which distils over. This operation is expressed by the following chemical formula:

Nitrate of Ammonia is

Ammonia, NH_4O, Nitric Acid, NO_5.

This is by the application of heat decomposed in its elements, 2 N (two atoms of nitrogen,) 4 H (four atoms of hydrogen) and 6 O (six atoms of oxygen,) but like in all similar decompositions, the elements are not separated uncombined, but at the moment of their separation enter in new combinations, namely, 4 of the 6 atoms of oxygen combine with 4 atoms of hydrogen and form 4 HO (four atoms of water), and the two remaining atoms of oxygen combine with the two atoms of nitrogen and form 2 NO (two atoms of nitrous oxid). The products

of this decomposition are sometimes passed through a washing-bottle, and if this is done, the operation is well enough as far as this is concerned, but the objectionable features are the next.

The gas is passed in a common wooden barrel filled with water; it is passed in from below, so that a quantity of water equal to the quantity of gas introduced continually flows out, causing a waste of water at least equal to the volume of all the gas manufactured, not to speak of the trouble of managing this water, when used in a locality without water-works; the gas being very soluble in water, will for a large portion be absorbed by it, and when left in this state, the diminishing volume of gas will continually be supplied by atmospheric air, when this has occasion to enter somewhere, thus diluting it and spoiling its effects. Sometimes the gas is passed in a very large india rubber bag, or in an apparatus partially made of india rubber, to keep it ready for use; from this bag it is passed in the smaller ones mentioned above, intended for its administration.

Now it is a fact known by experience to all who have attempted to preserve different kinds of gases in such bags, that after some days they all lose their characteristic properties, they are nearly always after a longer or shorter period of time changed in atmospheric air, and this by an interchange of their atoms through the infinitely small pores of the bag, with the atoms of the surrounding atmosphere, this action is called *endosmose*, and operates always when two different gases or fluids are separated by some membrane, however air-tight this membrane may be when placed between two gases or fluids of the same kind.

Another objection against india rubber bags is that they all deteriorate by age sooner or later, according to the quality of the rubber; rubber is nearly always undergoing a slow process of oxidation, as is proved by the analysis of fresh and of old rubber, the last always containing considerable oxygen, the fresh little or none; how gases act on rubber is illustrated by the peculiar disagreeable odor rubber tubes acquire when used to conduct common illuminating gas; the nitrous oxid also communicates a particular odor to the rubber bags, which in some instances is quite repugnant.

This imperfect mode of manufacturing, and worse method of administering nitrous oxid, has induced the Professor to attempt the construction of an apparatus by which all those difficulties are overcome, the apparatus not only being a substitute for the disgusting breathing bags, but also for the cumbersome barrel, and large expensive india rubber bags.

The success of his apparatus exceeds his most sanguine expectations, as it fulfils the following requisites:

1. *Completeness;* nothing else is wanted; it consists of three parts, first, the generator and purifier; second, the receiver and preserver; and third, the breathing apparatus.

2. *Cheapness.* Its expense is not more than the india rubber bags, barrels, or retorts, and it will be cheaper in the end, because of its

3. *Durability.* Being all of glass, it does not deteriorate in the course of time like wooden barrels, and much more the expensive india

rubber bags, which in a few years become useless, an experience made sooner or later by all who use them.

4. *Economy when preserving it.* No gas whatever is lost or wasted; a measured amount of nitrate of ammonia is sufficient to fill the receiver or reservoir with gas, which being of glass and floating exactly balanced in another glass vessel over diluted sulphuric acid, no gas is lost by endosmose or absorption of the water; the Professor found by a long series of experiments that of all the fluids and solutions tested, diluted sulphuric acid absorbs the gas least, and keeps it in the purest state.

5. *Economy in administering it.* As the gas is not drawn off in small bags, to be partially wasted, but is breathed directly from the reservoir, and all the exhaled gas returns to it by an entirely different channel, during which passage it is purified, no gas whatever can possibly be lost, but every part of what has been produced is made available to produce anæsthesia.

6. *Purity of the administered gas.* The purification spoken of above, is accomplished by passing the exhaled gas along a different channel through a solution of caustic potassa, which will necessarily retain the carbonic acid, and only permit the pure nitrous oxid to return to the reservoir. The strong affinity of caustic potassa for carbonic acid is known to all chemists, who ascertain the correct amount of carbon in organic compounds, by this power of a potash solution to absorb completely all carbonic acid in an atmosphere passing through it.

7. *Economy of time.* The apparatus is always in working order, the retort being kept filled with a dose of nitrate of ammonia; it is everywhere so provided for safety, that the operator has only to ignite the lamp, and need not meddle with it afterwards, except extinguishing it in about five minutes when the gas reservoir is filled, in five minutes more the white fumes have disappeared, and it may be used if necessary. The Professor has shown this at the meeting of the Dental Association in the city of New York, on Wednesday, November 17, where he for the first time exhibited his apparatus, and had one of the persons present fairly under the influence of the gas ten minutes after he commenced developing it.

However, it is better to wait longer and let the gas rest for one or two hours, then it is sweeter and more palatable, and the apparatus is just as appropriate for keeping the gas any length of time, as for developing it at a few minutes' notice.

Mr. P. E. Chase said that he thought that Dr. Vander Weyde had secured economy in administering the gas, by a fearful risk of health. Although the solution of caustic potassa might prove an adequate purifier so far as the carbonic acid was concerned, he did not think it would remove any contagious or miasmatic influence that might be contained in the breath. The same gas being breathed over and over by an unlimited number of patients, the reservoir might become so impregnated with tuberculous or eczematous virus, that the risk from inhalation would be far greater than from any ordinary exposure to contagion.

Mr. Fleury replied that it can be proved that the passing of the exhaled gas through the caustic potassa deprives the same of any virus or other poisonous substance that might lead to contagion.

A Comparison of some of the Meteorological Phenomena of Nov., 1863, *with those of* Nov., 1862, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.*
Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	Nov. 1863.	Nov. 1862.	Nov. 13 years.
Thermometer—Highest—degree, .	69·6°	71·6°	80·6°
" " date .	5th.	2d.	1st, 1860.
" Warmest day—Mean,	60·50	61·67	72·30
" " " date,	5th.	2d.	9th, 1857.
" Lowest—degree, .	25·00	27·00	16·00
" " date, . .	30th.	7th & 8th.	25th, 1860.
" Coldest day—Mean,	30·50	30·50	23·30
" " " date, .	30th.	7th.	25th, 1860.
" Mean daily oscillation,	14·37	13·40	13·46
" " " range, .	6·35	5·94	5·70
" Means at 7 A. M., .	42·45	40 67	41·17
" " 2 P. M., .	52·63	48·18	50·37
" " 9 P. M., .	46·12	43·25	44·40
" " for the month,	47·07	44·03	45·31
Barometer—Highest—Inches, .	30·249 in.	30·555 in.	30·661 in.
" " date, . .	23d.	16th.	12th, 1851.
" Greatest mean daily press.	30·232	30·509	30·520
" " date, . .	23d.	16th.	12th, 1851.
" Lowest—Inches, .	29·434	29·380	29·117
" " date, . .	17th.	20th.	19th, 1857.
" Least mean daily press.,	29·498	29·467	29·255
" " date, . .	17th.	20th.	19th, 1857.
" Mean daily range, .	0·185	0·159	0·184
" Means at 7 A. M., .	29 863	29·877	29·914
" " 2 P. M., .	29·804	29·823	29·871
" " 9 P. M., .	29·854	29·870	29·901
" " for the month,	29·840	29·857	29·895
Force of Vapor—Greatest—Inches,	0·463 in.	0·548 in.	0 832 in.
" " " date, .	15th.	20th.	8th, 1857.
" " Least—Inches, .	·074	·106	·055
" " " date, .	10th.	16th.	25th, 1857.
" " Means at 7 A. M.,	·208	·213	·226
" " " 2 P. M.,	·214	·228	·230
" " " 9 P M.,	·216	·224	·233
" " " for the month.	·213	·222	·230
Relative Humidity—Greatest—per ct.,	97 per ct.	100 per ct.	100 per ct.
" " " date,	15th.	7th.	Often.
" " Least—per ct.,	25·0	37·0	25·0
" " " date,	7th.	13th.	7th, 1863.
" " Means at 7 A.M.,	73·7	79·4	77 5
" " " 2 P.M.,	52·2	64·5	58·9
" " " 9 P.M.,	66·0	75·1	73·6
" " " for the month	64·0	73·0	70·0
Clouds—Number of clear days,* .	6	8	8·5
" " cloudy days, .	24	22	21·5
" Means of sky cov'd at 7 A.M.	57·3 per ct.	64·0 per ct.	59·9 per ct.
" " " " 2 P.M.	54·3	64·3	60·0
" " " " 9 P.M.	52·3	63·7	52·5
" " " for the month,	54·6	64·0	57·5
Rain and Melted Snow—Amount,	2·960 in.	4·455 in.	3·756 in.
No. of days on which Rain or Snow fell,	7	15	10·5
Prevailing Winds—Times in 1000,	N82°46·w·371	N 79° 0'w ·237	N70°41 w·262

* Less than one-third covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the AUTUMN *of* 1863, *with that of* 1862, *and of the same Season for* THIRTEEN *years, at Philadelphia, Pa.*—Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	Autumn, 1863.	Autumn, 1862.	Autumn for 13 years.
Thermometer—Highest—degree, .	83·00°	87·00°	95·00°
" " date, .	7th Sept.	8th Sept.	Sep. 12, 1851.
" Warmest day—Mean,	77·17	77·33	85·20
" " " date,	7th Sept.	8th Sept.	Sept. 6, 1854.
" Lowest—degree, .	25·00	27·00	16·00
" " date, . .	30th Nov.	Nov. 7 & 8.	Nov.25, 1860.
" Coldest day—Mean,	30·50	30·50	23·30
" " " date, .	30th Nov.	7th Nov.	Nov.25, 1860.
" Mean daily oscillation,	15·04	14·98	15·33
" " " range, .	5·17	5·24	5·29
" Means at 7 A. M., .	51·27	52·30	51·67
" " 2 P. M., .	61·73	62·83	62·78
" " 9 P. M., .	55·00	55·93	55·49
" " for the Autumn,	56·00	57·02	56·65
Barometer—Highest—Inches, .	30·312 in.	30·555	30·661 in.
" " date, . .	23d Sept.	16th Nov.	Nov.12, 1851.
" Greatest mean daily press	30·244	30·509	30·520
" " date, . .	23d Sept.	16th Nov.	Nov.12, 1851.
" Lowest—Inches, . .	29·281	29·307	29·012
" " date, . .	18th Sept.	27th Oct.	Oct. 26, 1857.
" Least mean daily press.,	29·460	29·467	29·059
" " date, . .	18th Sept.	20th Nov.	Oct. 26, 1857.
" Mean daily range, .	0·136	0·146	0·150
" Means at 7 A. M., .	29·908	29·874	29·938
" " 2 P. M., .	29·862	29·831	29·896
" " 9 P. M., .	29·906	29·868	29·921
" " for the Autumn,	29·892	29·858	29·918
Force of Vapor—Greatest—Inches,	0·784 in.	0·833 in.	0·991 in.
" " " date, .	17th Sept.	12th Sept.	Sept. 6, 1854.
" " Least—Inches, .	·074	·106	·055
" " " date, .	10th Nov.	16th Nov.	Nov.25, 1857.
" " Means at 7 A. M.,	·311	·339	·338
" " " 2 P. M.,	·324	·365	·357
" " " 9 P. M.,	·328	·369	·357
" " " for the Autumn,	·321	·358	·351
Relative Humidity—Greatest—per ct.,	97 per ct.	100 per ct.	100 per cent.
" " " date,	15th Nov.	7th Nov.	Often.
" " Least—per ct.,	25·0	32·0	23·0
" " " date, .	7th Nov.	3d Sept.	Oct. 21, 1859.
" " Means at 7 A.M.,	75·1	78·7	78·2
" " " 2 P.M.,	53·8	59·4	57·1
" " " 9 P.M.,	69·2	74·7	73·8
" " " for Autumn,	66·0	70·9	69·7
Clouds—Number of clear days,* .	26	31	29·4
" " cloudy days, .	65	60	61·6
" Means of sky cov'd at 7 A.M.	57·3 per ct.	58·8 per ct.	57·3 per ct.
" " " " 2 P.M.	55·6	55·3	55·4
" " " " 9 P.M.	44·5	52 8	42·6
" " " for Autumn,	52·5	55·6	51·8
Rain and Melted Snow—Amount,	6·601 in.	14·897 in.	10·520 in.
No. of days on which Rain or Snow fell,	24	32	27·2
Prevailing Winds—Times in 1000,	N75°50′W·201	N64°56′W·140	N76°27′W·230

* Less than one-third covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of DEC., 1863, *with those of* DEC., 1862, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	December, 1863.	December, 1862.	December for 13 years.
Thermometer—Highest—degree, .	60·00°	64·00	71·00°
" " date, .	14th.	15th.	2d, 1859.
" Warmest day—Mean,	54·17	55·00	62·80
" " " date,	13th.	15th.	2d, 1859.
" Lowest—degree, .	15·00	8·00	4·50
" " date, .	23d.	21st.	19th, 1856.
" Coldest day—Mean,	20·67	15·83	11·00
" " " date, .	23d.	20th.	18th, 1856.
" Mean daily oscillation,	13·26	12·74	12·35
" " " range, .	6·54	6·46	6·38
" Means at 7 A. M., .	30·87	32·24	31·70
" " 2 P. M., .	39·13	39·76	39·25
" " 9 P. M., .	34·68	34·71	34·59
" " for the month,	34·89	35·57	35·18
Barometer—Highest—Inches, .	30·495 in.	30·495 in.	30·678 in.
" " date, . .	7th.	20th.	18th, 1856.
" Greatest mean daily press.	30·423	30·401	30·611
" " date, . .	7th.	20th.	18th, 1856.
" Lowest—Inches, .	29·167	29·319	28·946
" " date, . .	14th.	16th.	9th, 1855.
" Least mean daily press.,	29·341	29·507	29·175
" " date, . .	14th.	16th.	9th, 1855.
" Mean daily range, .	0·223	0·197	0·212
" Means at 7 A. M., .	29·999	29·932	29·962
" " 2 P. M., .	29·935	29·895	29·922
" " 9 P. M., .	29·981	29·936	29·947
" " for the month, .	29·972	29·921	29·944
Force of Vapor—Greatest—Inches,	0·486 in.	0·377 in.	0·551 in.
" " " date, .	14th.	15th.	2d, 1859.
" " Least—Inches, .	·051 in.	·040	·025
" " " date, .	11th.	20th.	18th, 1856.
" " Means at 7 A. M.,	·142	·154	·143
" " " 2 P. M.,	·156	·163	·167
" " " 9 P. M.,	·145	·162	·155
" " " for the month,	·148	·160	·155
Relative Humidity—Greatest—per ct.,	96 per ct.	92 per ct.	100 per ct.
" " " date,	14th.	14th.	Often.
" " Least—per ct.,	35·0	31	23·0
" " " date, .	24th.	2d.	15th, 1861.
" " Means at 7 A.M.,	74·1	78·5	77·1
" " " 2 P.M.,	59·8	61·5	65·3
" " " 9 P.M.,	68·5	74·8	75·0
" " "for the month	67·5	71·6	72·5
Clouds—Number of clear days,* .	10	13	9·1
" " cloudy days, .	21	18	21·9
" Means of sky cov'd at 7 A.M.,	56·1 per ct.	52·6 per ct.	63·4 per ct.
" " " " 2 P.M.,	56·8	58·7	62·8
" " " " 9 P.M.,	47·4	42·6	46·1
" " " for the month,	53·4	51·2	57·4
Rain and melted Snow—Amount, .	4·871 in.	1·555 in.	3·631 in.
No. of days on which Rain or Snow fell,	10	8	9·9
Prevailing Winds—Times in 1000,	N72°0′ W ·243	N84°24′W ·301	N60°17′W ·285

* Less than one-third covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the year 1863, *with those of* 1862, *and of the last* TWELVE *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	1863.	1862.	12 Years.
Thermometer—Highest—degree, .	95·00°	95·50	100·50°
" " date, .	Aug. 10.	July 7.	July 21, 1854.
" Warmest day—Mean,	88·50	87·67	91·30
" " " date,	Aug. 10.	Aug. 9.	July 21, 1854.
" Lowest—degree, .	5·00	8·00	— 5·50
" " date, .	Feb. 5.	Dec. 21.	Jan. 23, 1857.
" Coldest day—Mean,	11·17	15·83	— 1·00
" " " date. .	Feb. 4.	Dec. 20.	Jan. 9, 1856.
" Mean daily oscillation,	14·63	15·21	15·14
" " " range, .	5·39	5·15	5·55
" Means at 7 A. M., .	49·98	49·22	49·71
" " 2 P. M., .	59·21	59·00	59·90
" " 9 P. M., .	53·21	52·53	53·14
" " for the year,	54·13	53·58	54·25
Barometer—Highest—Inches, .	30·671 in	30·555 in.	30·704 in.
" " date, . .	Feb. 4.	Nov. 16.	Jan. 28, 1853.
" Greatest mean daily press.,	30 553	30·509	30·611
" " date, . .	Jan. 18.	Nov. 16.	Dec. 18, 1856.
" Lowest—Inches, . .	29·127	29·216	28 884
" " date, . .	Jan. 16.	Feb. 24.	Ap. 21, 1852.
" Least mean daily press.,	29·298	29·390	28·959
" " date, . .	Jan. 16.	March 16.	Ap. 21, 1852.
" Mean daily range, .	0·157	0·160	0·156
" Means at 7 A. M., .	29·879	29·863	29·889
" " 2 P. M., .	29·835	29·822	29·849
" " 9 P. M., .	29·877	29·852	29·875
" " for the year,	29·864	29·846	29·871
Force of Vapor—Greatest—Inches,	0·980 in.	0·939 in.	1·059 in.
" " " date, .	Aug. 10.	Aug. 8.	June 30, 185[illegible]
" " Least—Inches, .	·027	·040	·013
" " " date, .	Feb. 4.	Dec. 20.	Feb. 6, 1855.
" " Means at 7 A. M.,	·316	·308	·324
" " " 2 P. M.,	·322	·316	·339
" " " 9 P. M.,	·332	·330	·344
" " " for the year,	·323	·318	·336
Relative Humidity—Greatest—per ct.,	100 per ct.	100 per ct.	100 per ct
" " " date,	Jan. 21.	Often.	Often.
" " Least—per ct.,	15·0	18·0	13·0
" " " date, .	April 26.	Ap. 27; May 8.	Ap. 13, 1852.
" " Means at 7 A. M.,	74·5	74·9	76·0
" " " 2 P. M.,	56·7	56·4	57·4
" " " 9 P. M.,	70·5	71·5	72·2
" " " for the year,	67·2	67·6	68·5
Clouds—Number of clear days,* .	93	100	110
" " cloudy days, .	272	265	255
" Means of sky cov'd at 7 A. M.,	63·4 per ct.	62·9 per ct.	59·8 per ct.
" " " " 2 P. M.,	63·9	62·8	60·3
" " " " 9 P. M.,	49·9	52·5	45·2
" " " for the year,	59·1	59·4	55·1
Rain and melted Snow—Amount, .	49·642 in.	45·656 in.	45·328 in.
No. of days on which Rain or Snow fell,	143	134	128
Prevailing Winds—Times in 1000,	N65°19′W·149	N58°40′W·159	S73°55′W·205

* Less than one-third covered at the hours of observation.

A General Abstract of the Meteorological Observations made at Philadelphia during the year 1863.—By Prof. James A. Kirkpatrick.

Latitude 39° 57½′ N. Longitude, 75° 10½′ W. from Greenwich. Height of Barometer fount, sixty feet above mean tide in the Delaware River.

1863. Months.	Thermometer.									Barometer.								Dew Point.			
	Maximum.	Minimum.	Range. Monthly.	Range. Mean daily.	Mean daily oscillation.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.	Highest.	Lowest.	Range. Monthly	Range. Mean daily.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.	Means. 7 A. M.	Means. 2 P. M.	Means. 9 P. M.	Means. Average.
	°	°	°	°	°	°	°	°	°	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	°	°	°	°
January,	61	14	47	5·60	12·90	33·95	40 95	36 64	37·18	30·571	29·127	1 444	·266	29·925	29 867	29·905	29·899	27·80	29 68	29·24	28 90
February,	54	5	49	7 54	13·57	30·46	37·70	34·04	34·07	30 671	29 345	1·326	·265	30·031	29·977	30·024	30·011	24 10	25 33	25 09	24·84
March,	63	15	48	6·47	13 81	32·29	40·94	35·82	36·35	30·384	29 422	·962	·214	29·882	29 829	29·880	29·864	25 38	25·54	26 83	25 92
April,	71	30	41	5·41	14·90	43·95	54·35	47·40	48·57	30·185	29·260	·925	·164	29·788	29 752	29 808	29 782	33·55	33 91	36·72	34·74
May,	90	40	50	5·43	19 15	59·32	71 76	62·64	64 57	29·975	29·295	·680	·085	29 783	29·736	29·769	29·763	50·00	49·10	52·19	50·43
June,	91½	52	39½	5 18	16·02	65·78	74·75	67 90	69 48	29·994	29·321	·673	083	29 743	29·712	29·756	29 737	54·22	53 94	55·13	54·43
July,	88	65	23	3 22	10 81	74·40	80·24	76·32	76·99	29 988	29 524	·461	·079	29·800	29·780	29·807	29 796	66 83	66·71	67·44	67 09
August,	95	58	37	3·79	16·00	74·95	85·50	78 05	79 50	30·119	29 699	·420	·100	29 878	29·850	29 868	29·865	66·00	63·00	65 00	64·67
September,	83	41	42	4 22	14·65	61·57	70·68	64·70	65·65	30·312	29 281	1 031	·116	29·940	29 896	29 939	29·925	52 51	54 32	54·47	53·77
October,	74	32	42	4·93	16·10	49·79	61·89	51·18	55 29	30 245	29·557	·688	·108	29·920	29 885	29 925	29·910	43·29	43 54	44·93	43·92
November,	69	25	44	6·35	14·37	42·45	52·63	46 12	47·07	30·249	29·434	·815	·185	29·863	29 804	29·854	29 840	34·39	34·16	35·00	34·52
December,	60	15	45	6·54	13 26	30 87	39·13	34·68	34 89	30·495	29·167	1·328	·223	29·999	29·935	29·981	29 972	23·59	25·74	25·10	24 81
Annual means,	95	5	90	5·39	14·63	49·98	59·21	53·21	54·13	30 671	29·127	1·544	·157	29 879	29·835	29 877	29·864	41·81	42·08	43·10	42 33
Winter,	64	5	59	6·53	13·07	32·22	39·47	35·13	35·61	30 671	29·127	1 544	·243	29 963	29·913	29 955	29 944	26·12	27·43	27 29	26·9
Spring,	90	15	75	5·77	15 95	45·19	55 68	48·62	49 83	30·384	29 260	1·124	·154	29·818	29·772	29 819	29 803	36·31	36 19	38·58	37·0
Summer,	95	52	43	4·06	14·28	71·71	80·16	74 09	75 32	30·119	29 321	·798	·087	29 807	29 781	29 810	29 799	62·35	61·22	62 62	62·0
Autumn,	83	25	58	5 17	15 04	51·27	61·73	55·00	56·00	30·312	29·281	1 031	·136	29 908	29 862	29·906	29 892	43·40	44 01	44 80	44·07
Means for 12 years,	100½	—5½	106	5·55	15·11	49·71	59·90	53·14	54·25	30·704	28 884	1·820	·156	29·889	29·849	29 875	29·871		43·40		